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Class I " Pacific " locomotives and tenders of the Belgian National Railways Company,

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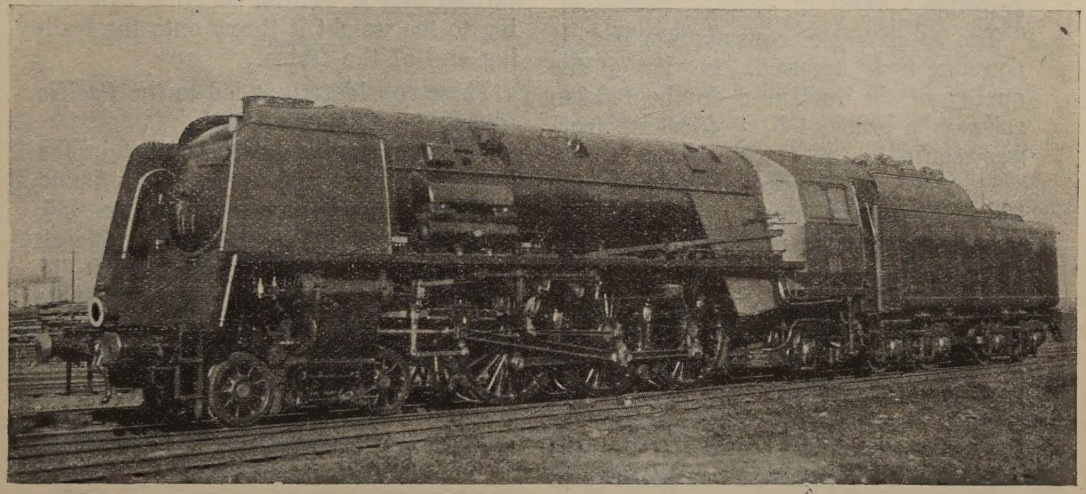


Starting with the 1935 Summer service, the heaviest fast trains known as « trains-blocs » and international trains had to be worked throughout the year over the Brussels-Herbesthal and Brussels-Ostend lines in times based on a steady speed of 120 km. (75 miles) an hour on the level. The overall booked speed was nearly 100 km. (62 miles) an hour, in spite of slacks and having to accelerate the trains on heavy gradients at the start of certain runs. The programme also involved working trains of 400 tons at an average speed of 80 km. (50 miles) an hour on the Luxembourg line, with its long 1 in 62 gradients. For these reasons the purchase of some fifteen powerful high-speed engines by the Company was deemed opportune.

* * *

Essential features selected by the Belgian National Railways Company.

General.

In view of the above conditions, the locomotives had to be more powerful than the previous *Pacifics*, and also be able to develop very high tractive efforts at starting, so that simple expansion was to be preferred. The increase in weight through the greater power limited proportionally the dynamic load on the track and in turn prevented a high percentage of the reciprocating weight being balanced. Four cylinders then became desirable.

The specific coal consumption had, if possible, to be reduced. In view of the quality of the fuel used on the Belgian railways a grate of 5 m^2 (53.8 sq. feet) was required.

In view of the present tendency to higher boiler pressures through improved efficiency, the pressure of 18 kgr/cm^2 (256 lb. per sq. inch) was selected. For a boiler with this pressure, with so large a grate area and with adequate water capacity and steam volume, the use of nickel steel was attractive as its greater tensile strength meant the retention of the ordinary thickness of plate. By distributing the weight of the boiler over three pairs of wheels, with a maximum axle load of 23 to 24 tons, the adhesive weight would be sufficient.

A leading bogie was essential for a high-speed locomotive. As the piston stroke had been fixed at 720 mm. (28 3/8 inches) in order to have sufficient metal on the built-up crank axle webs between adjacent crank pins, the cylinder diameter was fixed at 420 mm. (16 1/2 inches) so as to obtain full power at 20 % cut-off.

The tender was to have a large water and coal capacity, so as to be able to run long distances without a stop and to avoid having to coal at the end of an outward trip. The capacities were fixed at 38 m^3 (8 360 Br. gall.) and 10 tons respectively. The design selected was that of a tender carried on two bogies.

Such a tender is so long that the length of the locomotive had to be restricted to suit existing turntables. The length of the firebox had therefore to be markedly reduced so that the idea of a firebox between the frames had to be given up in view of the grate area required. The wide box required had therefore to be carried over a trailing carrying axle owing to the weight it threw onto the trailing end of the frame.

These considerations led to the *Pacific* (4-6-2) type being selected.

This new engine was classified in the Belgian railway registers as Class I and the locomotives, numbered 101 to 115, were to be put into service between March and June 1935. The 38-m^3 (8 360 Br. gall.) tenders were numbered 38101 to 38115.

The drawings, subject to the approval of the Chief Mechanical Engineer, were got out by the Tubize works of the « Ateliers Métallurgiques » in the case of the locomotive, and by the « Forges et Fonderies de Haine-St-Pierre » for the tender, the specifications, being as follow.

Boiler.

Firebox and casing.

The round-top outer firebox had to have amply opened-out water spaces and the inner box, without a combustion chamber, a crownsheet sloping towards the back and curved transversely.

The outer sheets were to be made of 2 to 2.3 % nickel steel. The firebox was to be of copper, like the stays.

A firebrick arch simply carried on water tubes was to be fitted.

Two horizontally-hinged self-closing firebox doors giving an opening of 400 × 310 mm. (15 3/4 in. × 12 3/16 in.), of the standard Belgian National Railways type, had to be fitted.

A steam turret with the different steam valves, Cole type 89 mm. (3 1/2 inch) diameter safety valves, and the usual fittings used on Belgian locomotives, had to be supplied.

The regulator lever had to be arranged on the left-hand side of the firebox.

Barrel.

The barrel plates were to be made of the same nickel steel as already mentioned. The distance between tube plates was fixed at 6 m. (19 ft. 8 1/4 in.), and the average diameter of the barrel, 1.80 m. (5 ft. 10 7/8 in.). The flues were to be 128 × 137 mm. (5 3/64 in. × 5 25/64 in.) with 30.5 × 38-mm. (1 3/16 in. × 1 1/2 in.) superheater elements, and the small tubes, 50 × 55 mm. (1 31/32 in. × 2 11/64 in.).

Thirteen of the locomotives were to be fitted with double-seated regulator valves, and the other two with multiple valve regulators mounted solid with the header, to make it possible to supply superheated steam to the auxiliaries.

A double-circuit superheater with separate headers to allow for expansion and prevent loss of heat to the saturated side was designed to give a temperature of at least 385° C. (725° F.) at full power.

A second dome into which the feed water is discharged had to be fitted in front of the steam dome and to contain a mud collector.

Smoke box.

The blast was to be arranged on the central line of the inside cylinders which were to be located sufficiently forward of the driving axle to get well proportioned rods; the smoke box was consequently to be extended considerably.

The engines were to be fitted with a double blast pipe, the standard practice for all powerful Belgian locomotives. The design used was to be selected from the best in use at the time.

Frame.

Bar frames were specified as being most rigid and least likely to get out of square. So as to make full use of the cylinders to cross-brace the frame, they were to be arranged in line and cast in pairs; they were to be bolted together on the centre line of the engine.

Owing to its great influence in steadying the engine when running, constant self-centering gear incorporating the « Woodard » type of links, which is being used more and more on American bogies and trucks, was selected.

The spring gear was to consist of laminated springs over the axle boxes in conjunction with equalisers so as to obtain three-point suspension, one point being the bogie centre.

The boiler barrel was to be fastened at the leading end to the inside cylinders, and the barrel rings supported by flexible vertical plates. The firebox was to be carried on expansion brackets at its front end and be supported at the back end by a vertical flexible plate.

The coupled axle boxes were to be cast steel with pressed-in American type brasses, with half circular tops without flanges.

The carrying axles were to have roller-bearing boxes.

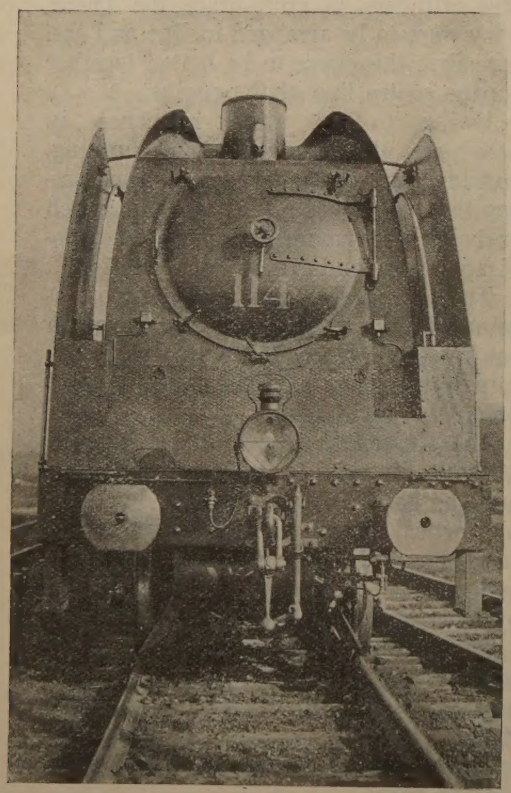
Wheel sets.

A self-balanced built-up crank axle was specified. The pins were to be of semi-hard heat-treated steel and the webs heat-treated nickel-chrome steel.

The wheels were to be of the usual Belgian standard sizes; bogie wheels 0.90 m. (2 ft. 11 1/2 in.), coupled wheels 1.98 m. (6 ft. 6 in.), trailing wheels 1.262 or 1.067 m. (4 ft. 1 43/64 in. or 3 ft. 6 in.).

Motion.

The cylinders could be slightly inclined. They were to be cast steel with cast iron cylinder and steam chest linings.



The lubricating oil for the valves and pistons was to be delivered to the steam chests.

The cylinders had to be fitted with 70-mm. (2 3/4 inch) diameter relief cocks of the standard Belgian pattern.

Double-dished hollow cast steel pistons with cast iron rims cast on were specified.

The piston valves were to be 250 mm. (9 27/32 inches) in diameter and of the double-admission type. The inside valves were to be driven by a conjugated motion consisting of a horizontal lever with two short levers connected together to the valve spindle of the outside gear, of the Walschaerts type.

Cast steel crossheads were required.

The inside connecting rods were to drive the crankshaft of the first pair of coupled wheels, and the outside rods the second pair of wheels, also carrying the return cranks.

The balancing of the reciprocating parts was to be designed for a maximum dynamic augment of 1 500 kgr. (3 300 lb.) on any pair of wheels at a speed of 120 km. (75 miles) an hour.

Lagging.

The domes, feed water heater, sand box and piping were to be encased by lagging resulting in an oval section, which was to be connected to the cab by inclined surfaces and the sides of the tender arranged to follow the same lines, so as to streamline the whole, at least in its upper part.

Negotiating curves.

The engine coupled to its tender must be able to run through a curve of 120 m. (6 chains) radius.

* * *

The leading dimensions of these engines, as built, are as follows :

Boiler.

Pressure		18 kgr./cm².	*(256 lb. per sq. inch)*
Outer firebox.			
Outside length	at the top	2.490 m.	*(8′ 2″)*
	at the bottom	2.512 m.	*(8′ 2 29/32″)*
Inside width	at the crown	1.790 m.	*(5′ 10 15/32″)*
	at the bottom	2.432 m.	*(7′ 11 3/4″)*
Distance between the top and the crown		0.580 m.	*(1′ 10 13/16″)*
Height above rail level of the front end of the foundation ring		1.255 m.	*(4′ 1 25/64″)*
Thickness of nickel-steel plates	crown plate	21 mm.	*(53/64″)*
	side walls	14 mm.	*(35/64″)*
Inner firebox (copper).			
Inside length	at the top	2.215 m.	*(7′ 3 13/64″)*
	at the bottom	2.275 m.	*(7′ 5 35/64″)*
Inside width	at the top	1.535 m.	*(5′ 7/16″)*
	at the bottom	2.200 m.	*(7′ 2 5/8″)*
Inside height above foundation ring	at the front end	2.026 m.	*(6′ 7 3/4″)*
	at the back end	1.570 m.	*(5′ 1 53/64″)*
Inside height above boiler centre line	at the front	0.401 m.	*(1′ 25/32″)*
	at the back	0.360 m.	*(1′ 2 3/16″)*
Slope of crown		1 in 53.	
Thickness of	crownsheet	17 mm.	*(11/16″)*
	side walls	17 mm.	*(11/16″)*
	tube plate	30 mm.	*(1′ 3/16″)*
Length of arch		1.126 m.	*(3′ 8 5/16″)*
Arch tubes	number	4	
	inside diameter	67 mm.	*(2 41/64″)*
	thickness	4.5 mm.	*(0.177″)*
Volume of firebox above the grate (arch and arch tubes excluded)		13.150 m³	*(464.4 cu. ft)*
Grate.			
Length		2.275 m.	*(7′ 5 35/64″)*
Width		2.200 m.	*(7′ 2 5/8″)*
Slope		10°	
Proportion of air passages to the grate area		37 %	
Barrel.			
Inside diameter	first ring	1.800 m.	*(5′ 10 5/64″)*
	middle ring	1.836 m.	*(6′ 9/32″)*
	third ring, at front end	1.800 m.	*(5′ 10 5/64″)*
	third ring, at back end	1.880 m.	*(6′ 2″)*
Thickness of nickel-steel plates		18 mm.	*(45/64″)*
Thickness of straps	outside	14 mm.	*(35/64″)*
	inside	16 mm.	*(5/8″)*
Thickness of smokebox tube plate		25 mm.	*(63/64″)*

Tubes.

Number of flues and tubes	flues	38	
	tubes	131	
Inside diameter of	flues	128 mm.	*(5 3/64″)*
	tubes	50 mm.	*(1 31/32″)*
Thickness of flues and tubes (steel)	flues	4.5 mm.	*(0.177″)*
	tubes	2.5 mm.	*(0.0985″)*
Distance between tube plates		6.000 m.	*(19′ 8 1/4″)*

Superheater elements.

Inside diameter	30.5 mm.	*(1 3/16″)*
Thickness	3.75 mm.	*(0.147″)*
Distance of spear end from firebox tube plate	300 mm.	*(11 13/16″)*

Heating surface.

Direct	firebox (taken above the grate)	17.32 m²	*(186.4 sq. ft.)*
	arch tubes	2.40 m²	*(25.8 sq. ft.)*
Indirect	gas side	215.06 m²	*(2 314.9 sq. ft.)*
	water side	234.02 m²	*(2 519.0 sq. ft.)*
Total (gas side)		234.78 m²	*(2 527.2 sq. ft.)*
Superheating surface (outside development)		111.70 m²	*(1 202.3 sq. ft.)*
Ratio of superheating to heating surface		0.476	
Evaporative area of the water (stays deducted)		12.40 m²	*(133.5 sq. ft.)*
Volume of water (15 cm. = 6 inches above the topmost part of inner firebox)		10.840 m³	*(382.8 cu. ft.)*
Volume of steam (15 cm. = 6 inches above the topmost part of inner firebox)		3.750 m³	*(132.4 cu. ft.)*

Smoke box.

Inside length	at the top	3.1525 m.	*(10′ 4 9/64″)*
	at the bottom	3.4905 m.	*(11′ 5 25/64)*
Inside diameter		1.836 m.	*(6′ 9/32″)*
Thickness of wrapper		13 mm.	*(33/64″)*

Chimney.

Inside diameter of each of the two pipes of the Kylchap blast.	0.475 m.	*(18 11/16″)*
Inside length of the chimney with the Lemaître blast	1.030 m.	*(3′ 4 35/64″)*
Inside width of the chimney with the Lemaître blast	0.500 m.	*(19 11/16″)*
Height of the top above rail level	4.280 m.	*(14′ 1/2″)*

Section of gas passages.

Through the ashpan doors		0.70 m²	*(7.53 sq. ft.)*
Through the grate		1.66 m²	*(17.87 sq. ft.)*
Through the tubes	flue tubes where most reduced by elements	0.2918 m²	*(3.14 sq. ft.)*
	small tubes	0.2572 m²	*(2.77 sq. ft.)*
	total	0.5490 m²	*(5.91 sq. ft.)*
At choke of chimney	Kylchap blast	0.3544 m²	*(3.81 sq. ft.)*
	Lemaître blast	0.4613 m²	*(4.96 sq. ft.)*

Ratio of passages through	the flues and tubes	1.134
	the flues and tubes combined and the grate	0.109
	the ashpan doors and the grate	0.140

Sectional area of steam passages.

Through regulator (fully open)	3.0150 dm²	*(50 sq. in.)*
Inlet side, saturated steam header	3.1416 dm²	*(54.5 sq. in.)*
Inlet side, superheater elements	2.7740 dm²	*(43.0 sq. in.)*
Outlet side, superheater elements	2.7740 dm²	*(43.0 sq. in.)*
Outlet side, superheater header	5.0894 dm²	*(78.9 sq. in.)*
Through the steam pipes (two of 180 mm. = 7 3/32 inches inside diameter)	5.0894 dm²	*(78.9 sq. in.)*

Frame.

Main frames.

Length	10.220 m.	*(33' 6 7/16")*
Thickness	0.115 m.	*(4 33/64")*
Depth in line with the cylinders	0.250 m.	*(9 7/8")*
Depth of the bar above the driving boxes	0.200 m.	*(7 7/8")*
Depth between the wheels — total	0.834 m.	*(2' 8 53/64")*
Depth between the wheels — top bar	0.171 m.	*(6 3/4")*
Depth between the wheels — bottom bar	0.125 m.	*(4 29/32")*
Width between main frames	1.057 m.	*(3' 5 5/8")*
Side play — of bogie frame on bogie centre line	2 × 102 mm.	*(2 × 4")*
Side play — of truck frame on axle centre line	2 × 155 mm.	*(2 × 6 1/8")*

Wheels and axles.

Diameter of the wheels on the tread (new tyres) — bogie	0.900 m.	*(2' 11 1/2")*
Diameter of the wheels on the tread (new tyres) — coupled	1.980 m.	*(6' 6")*
Diameter of the wheels on the tread (new tyres) — carrying	1.067 m.	*(3' 6")*
Tyre thickness — bogie and truck wheels	76 mm.	*(3")*
Tyre thickness — coupled wheels	81 mm.	*(3 3/16")*
Thickness of flanges at 10 mm. (3/8 inch) from tread — bogie and trailing carrying	32.5 mm.	*(1 9/32")*
Thickness of flanges at 10 mm. (3/8 inch) from tread — 1st and third coupled	32.5 mm.	*(1 9/32")*
Thickness of flanges at 10 mm. (3/8 inch) from tread — intermediate driving	17 mm.	*(43/64")*
Distance between inside faces of tyres	1.360 m.	*(4' 5 35/64")*
Journals — Diameter — bogie	0.180 m.	*(7 3/32")*
Journals — Diameter — driving axles and trailing coupled (with centre hole 60 mm. (2 3/8 in.) diameter	0.250 m.	*(9 7/8")*
Journals — Diameter — trailing carrying axle	0.150 m.	*(5 29/32")*
Journals — Length — bogie	0.128 m.	*(5 3/64")*
Journals — Length — driving and trailing coupled	0.258 m.	*(10 5/32")*
Journals — Length — trailing carrying	0.280 m.	*(11 1/32")*
Journals — Distance between centres — bogie	1.016 m.	*(3' 4")*
Journals — Distance between centres — crank axle	1.192 m.	*(3' 10 15/16")*
Journals — Distance between centres — middle and trailing coupled	1.172 m.	*(3' 10 5/32")*
Journals — Distance between centres — trailing carrying	2.058 m.	*(6' 9")*
Wheel seats — Diameters — bogie	0.178 m.	*(7")*
Wheel seats — Diameters — coupled (60 mm. (2 3/8 in.) centre hole)	0.255 m.	*(10")*
Wheel seats — Diameters — trailing and carrying	0.150 m.	*(5 29/32")*
Wheel seats — Length — bogie	0.182 m.	*(7 5/32")*
Wheel seats — Length — coupled	0.195 m.	*(7 43/64")*
Wheel seats — Length — truck	0.305 m.	*(12")*

Crank pins	Diameter	inside driving crank pin	0.240 m.	*(9 7/16″)*
		crank axle coupling rod pin	0.130 m.	*(5 1/8″)*
		outside driving crank pin	0.155 m.	*(6 1/8″)*
		straight axle coupling	0.165 m.	*(6 33/64″)*
		trailing coupled	0.130 m.	*(5 1/8″)*
	Length	inside driving	0.140 m.	*(5 1/2″)*
		crank axle coupling rod	0.100 m.	*(3 15/16″)*
		outside driving	0.142 m.	*(5 19/32″)*
		straight axle coupling	0.125 m.	*(4 29/32″)*
		trailing coupled	0.100 m.	*(3 15/16″)*
	Distance between centres measured across the engine	inside driving	0.530 m.	*(1′ 8 7/8″)*
		crank axle coupling	1.953 m.	*(6′ 4 29/32″)*
		outside driving	2.220 m.	*(7′ 3 25/64″)*
		straight axle coupling	1.953 m.	*(6′ 4 29/32″)*
		trailing coupling	1.953 m.	*(6′ 4 29/32″)*
Springs	Length between centres of spring hangers	bogie	1.016 m.	*(3′ 4″)*
		driving wheels	1.100 m.	*(3′ 7 5/16″)*
		trailing coupled	1.000 m.	*(3′ 3 3/8″)*
		trailing truck	1.120 m.	*(3′ 8 5/64″)*
	Number and section of ribbed plates	bogie 18 plates	120 × 13 mm.	*(4 23/32″ × 33/64″)*
		driving 16 plates	90 × 13 mm.	*(3 17/32″ × 33/64″)*
		trailing coupled. 15 plates	90 × 13 mm.	*(3 17/32″ × 33/64″)*
		trailing truck 12 plates	120 × 13 mm.	*(4 23/32″ × 33/64″)*
Side play	between the inside face of the axle box and the coupled wheel boss		1 mm.	*(0.0395″)*
	of the coupled boxes in their guides	at the middle	0.2 mm.	*(0.0079″)*
		at the top and bottom	2 × 2 mm.	*(2 × 0.079″)*

Motion and valve gear.

Motion.

Cylinder diameter	0.420 m.	*(16 1/2″)*
Piston stroke	0.720 m.	*(28 3/8″)*
Section of one cylinder steam pipe	0.0252 m²	*(39.1 sq. in.)*
Clearance volume: inside cylinders	15.682 dm³	*(957 cu. in.)*
Clearance volume: outside cylinders	16.029 dm³	*(978 cu. in.)*
Volume swept by pistons	99.752 dm³	*(6 088 cu. in.)*
Ratio clearance volume / swept volume: inside cylinders	15.7 %	
Ratio clearance volume / swept volume: outside cylinders	16.03 %	
Slope of the cylinders to the horizontal, both outside and inside	1 in 33	
Length of driving rods: outside	3.300 m.	*(10′ 10″)*
Length of driving rods: inside	2.015 m.	*(6′ 7 5/16″)*
Ratio length of driving rods / crank pin radius: outside gear	9.166	
Ratio length of driving rods / crank pin radius: inside gear	5.597	

Valve gear.

Diameter of piston valves	0.250 m.	*(9 27/32″)*
Maximum travel	0.176 m.	*(6 15/16″)*
Section of inlet passage of a valve	0.1092 m²	*(169 sq. in.)*
Section of the cylindrical passage of a sleeve	0.0471 m²	*(73 sq. in.)*
Section of a set of ports fully uncovered	0.0325 m²	*(50 sq. in.)*
Section of the passage at the base of the blast pipe	0.1360 m²	*(210 sq. in.)*

Pre-admission	outside cylinders		6.98 mm.	*(0.275″)*
	inside cylinders	front face	3.5 mm.	*(0.1377″)*
		back face	12 mm.	*(15/32″)*
Steam lap	outside cylinders		45 mm.	*(1 49/64″)*
	inside cylinders	front	48.5 mm.	*(1 29/32″)*
		back	40 mm.	*(1 37/64″)*
Pre-exhaust : outside and inside volume			0	

Weight.

Empty		114.2 t.	*(112.4 Engl. tons)*
Average working order	1st pair of wheels	16.25 t.	*(16.0 Engl. tons)*
	2nd »	16.25 t.	*(16.0 Engl. tons)*
	3rd »	24 t.	*(23.6 Engl. tons)*
	4th »	24 t.	*(23.6 Engl. tons)*
	5th »	24 t.	*(23.6 Engl. tons)*
	6th »	21.5 t.	*(21.2 Engl. tons)*
	Total	126.0 t.	*(124.0 Engl. tons)*
Adhesive		72.0 t.	*(70.9 Engl. tons)*

Figure 1 shows the general layout of the locomotive.

Some particular features of the engine.

Boiler.

The top of the copper firebox is almost flat whilst that of the outer firebox is cylindrical. This design is used on all recent powerful locomotives of the Belgian National Railways Company.

The outer firebox casing, made of three pieces, is of 2 to 2.3 % nickel steel with a minimum tensile strength of 52 kgr./cm² (33 Engl. tons p. sq. inch), a minimum elongation of 23 % and a resilience of not less than 15 Kg.-M./cm².

The top of the outer firebox back plate, also of nickel steel, is stiffened by eight longitudinal stays the other ends of which are fastened to the wrapper plate. The latter is strengthened by 6 cross stays 42 mm. (1 21/32 inches) in diameter. All these large stays are of 2 to 3 % nickel steel with a minimum tensile strength, after heat treatment, of 55 kgr./mm² (34.9 Engl. tons per sq. inch), the elastic limit being at least 38 kgr./mm² (24.13 Engl. tons per sq. inch).

The barrel centre line is 2.97 m. (9 ft. 9 in.) above rail level, and the three barrel rings are made of nickel steel to the same specification as that of the outer firebox plates.

The top of the smoke-box tube plate is stiffened by a horizontal plate 580 mm. (1 ft. 10 13/16 in.) wide with gusset plates.

The shaking grate has a lever-operated drop section. The boiler is fed with an ACFI feed water heater, RM type, with a 305-mm. (24 in.) diameter pump suitable for a sustained output of 21 m³ (742 cu. ft.) per hour. A non-lifting Friedmann No. 13 injector is provided as standby.

Superheater. — A type C. S. (Superheater Company) superheater is fitted with double and separate headers in cast steel, one for saturated, and the other for superheated steam. The elements have spherical joints and forged spear ends. The superheater has been

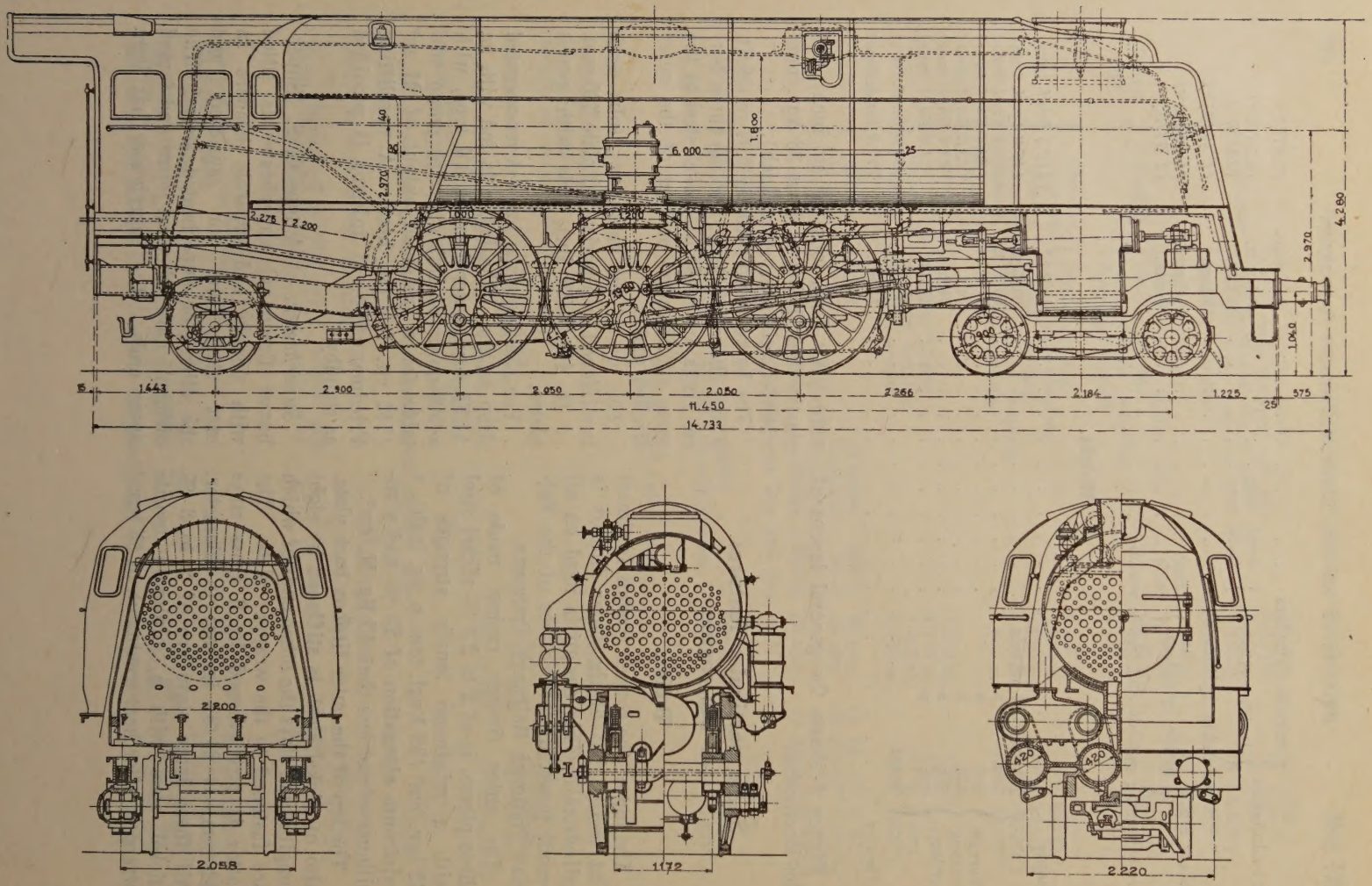

6.000
1.600
2.370
2.275
2.200
4.280
2.970
1.040
1.443
2.900
2.050
2.050
2.266
2.184
1.225
575
25
11.450
14.733
2.200
2.058
1172
2.220

Fig. 1.

given very ample proportions, the aim being to ensure a good superheat and reduce the pressure losses, so as to get as nearly as possible full boiler pressure in the steam chests.

Regulator. — The double-seated balanced type regulator fitted in the back dome is operated by a hand lever above the reversing gear, the pull rod being outside the barrel. The maximum area through the regulator and the main steam pipe limits the maximum steam speed to just over 18 m. (59.6 feet) per second.

The middle of the centre barrel ring, where the steam is thus collected, is the point where there is least likelihood of priming.

Two of the fifteen locomotives are fitted with a Superheater Company's multiple-valve regulator fitted in line with the superheater steam header. By rotating a cam shaft, superheated steam is first of all admitted into a balancing chamber by a pilot valve after which each valve is raised in turn. By using a number of small valves, the regulator can be gradually opened to its maximum. There is less likelihood of slipping and the regulator remains tight longer as the small valves wear less.

Blast pipes. — Three of the locomotives are fitted with the Kylchap, and twelve with the Lemaître blast pipe.

With the former (fig. 2) there are two nozzles, 140 mm. (5 1/2 inches) in diameter, two Kylälä intermediate petticoat pipes with four passages, as perfected by M. Chapelon, and two chimneys, of 475 mm. (18 45/64 inches) diameter at the waist, in a common casing. This double chimney was successfully applied by M. Legein to the old Belgian State *Pacifics*, in 1925, and has since been fitted to the modern Belgian locomotives, as opportunity arises. With this arrangement, a blast pipe with large steam nozzles requiring less height whilst remaining within the loading gauge can be obtained.

The second design (fig. 3) gives a still greater chimney area for exhausting the mixture of steam and gases. The chimney section is oblong, and measures 1.03 m. × 0.50 m. (40 in. by 19 11/16 in.). Eight nozzles 45 mm. (1 49/64 inches) in diameter exhaust into it just above its base. A central longitudinal orifice 500 mm. by 15 mm. (19 11/16 in. × 19/32 in.) is fitted on top of the main blast pipe, about 300 mm. (11 3/4 inches) below the small nozzles.

Although the ratio of the blast pipe area in the two designs is about 3 to 2, the back pressures and vacua recorded in tests at different rates of working are about the same.

Frame.

The boiler is carried at the front end by its smoke box which rests on a saddle forming the top of the two cylinder blocks, and by an intermediate motion cross stay. It also rests on two side expansion brackets on the forward end of the trailing truck frame. It is also held down by three flexibile plates placed on edge, one under the back water legs of the firebox.

The side frames, although stiff in themselves, have been cross-braced by cast steel box girder stays, so that the frame has been made very rigid, without any sacrifice as regards accessibility, or facility in taking down the main parts. The use of four cylinders in line and the substantial way in which they are bolted up keeps the frame square.

The engine and tender can negotiate a curve of 120 m. (6 chains) radius

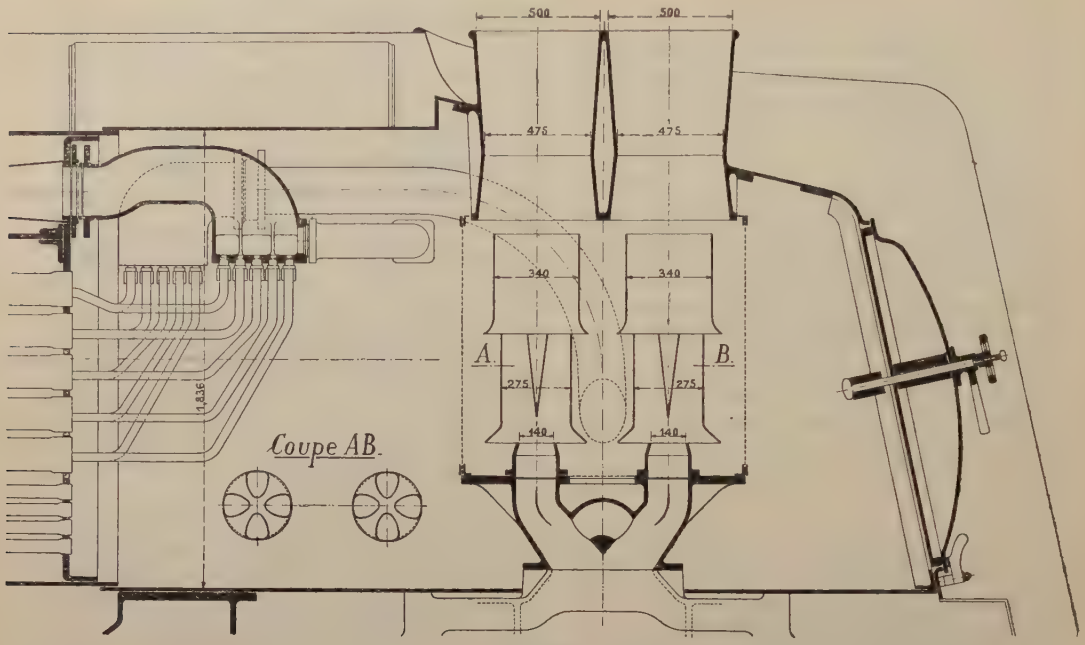

500
500
475
475
340
340
A.
B.
275
275
140
140
1836
Coupe AB.

Fig. 2.

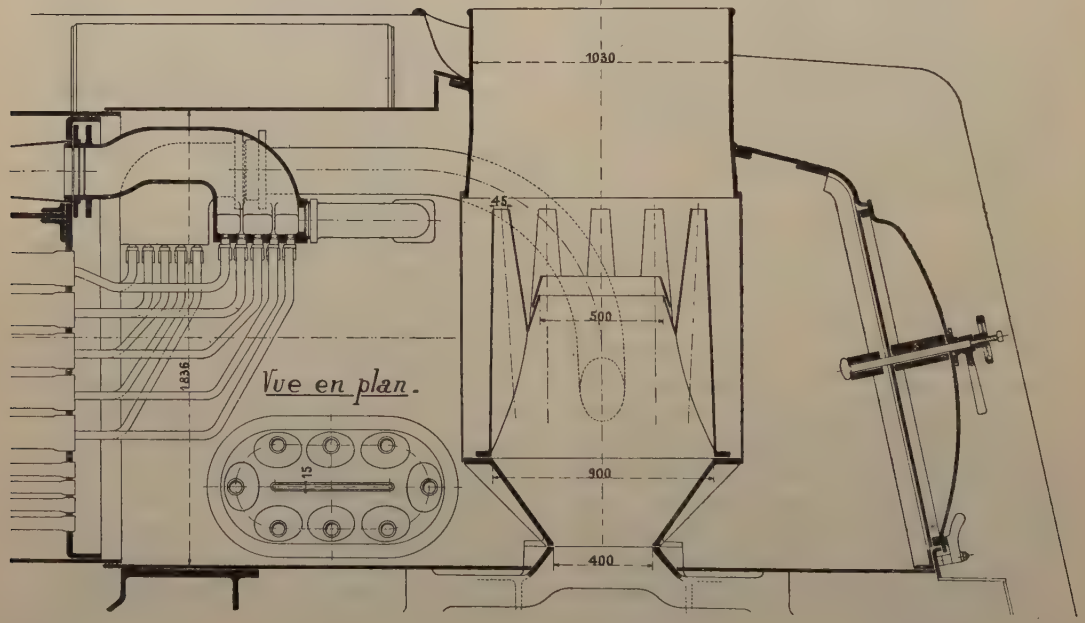

1030
45
500
900
400
1836
Vue en plan.
15

Fig. 3.

thanks to the lateral displacement of the bogie and trailing truck, and to the flanges of the middle coupled wheels being thinned down 15 mm. (19/32 inch).

Spring gear. — All parts of the spring gear can be got at easily through the use of bar frames with the laminated springs over the top of the axle boxes. The loads moreover act without any eccentricity on the vertical symmetrical planes through the frames and journals.

The loads are correctly distributed over the different pairs of wheels by using longitudinal equalisers between the coupled wheels and the trailing carrying pair. The load is adjusted by means of a box nut on the rod connecting the rear end of the trailing coupled wheel springs with the truck equaliser; no other centering gear is required.

Silicon-manganese steel was specified for the bearing springs.

Bogie and trailing truck.

The Delta constant self-centering arrangement, shown in figures 4 and 5, applied to both bogie and truck, has been found to be most effective; the engine takes curves at high speeds perfectly. The load is transferred to the bogie through a centre bearing resting on two ogival shaped links O through inclined planes *a, b, c,* at an angle of 36°. When on a curve, these links roll on these inclined planes, rocking about one or the other end flange on their base. These flanges bear in the corresponding grooves in the bogie bolster, and lift the front end of the locomotive up to a maximum of 42 mm. (1 21/32 inches) when the centering force thereby set up is 26 × 0.4 = 10.4 t. (10.2 Engl. tons).

The cast steel monoblock bogie frame weighs 1 770 kgr. (3 905 lb.) including the centre and the links. The load is transferred to the axle boxes through laminated springs carried between the webs of the longitudinal equalisers.

The triangular shaped truck frame is also a monoblock steel casting weighing 2 230 kgr. (4 920 lb.). The side members are tubular and the longitudinal equalisers are arranged inside them. The trailing axle has outside journals and the rolling-bearing axle boxes are carried in an inverted U-shaped opening cast in the side members of the frame. A laminated spring is fitted over each box.

Each of the two links of the trailing truck cradle carries over a load of 4 300 kgr. (9 490 lb.). The centering force is 460 kgr. (1 015 lb.), and the maximum lift at the back end of the locomotive is limited to 23 mm. (29/32 inch).

Wheel sets. — In view of the great load, thicker tyres, such as used on the latest *Mikado* engines, have been fitted on the driving and coupled wheels.

The crank axle is built up of five parts. The heat-treated nickel-chrome steel webs are 132 mm. (5 13/64 inches) wide and are intended to balance the axle on itself, the wheel centres having no counterbalance weights. The pins and the middle like the straight axles are made of heat treated semi-hard steel.

The coupled axles have no collars, the lateral forces being taken by bronze discs, fastened to the outside of the axle boxes, which butt up against heat-treated hardened steel discs fastened to the inside of the wheel bosses.

Balancing. — The reciprocating parts are balanced to limit the dynamic augment at 120 km. (75 miles) an hour to 6 % of the static load on each wheel. When applying Professor Dalby's method

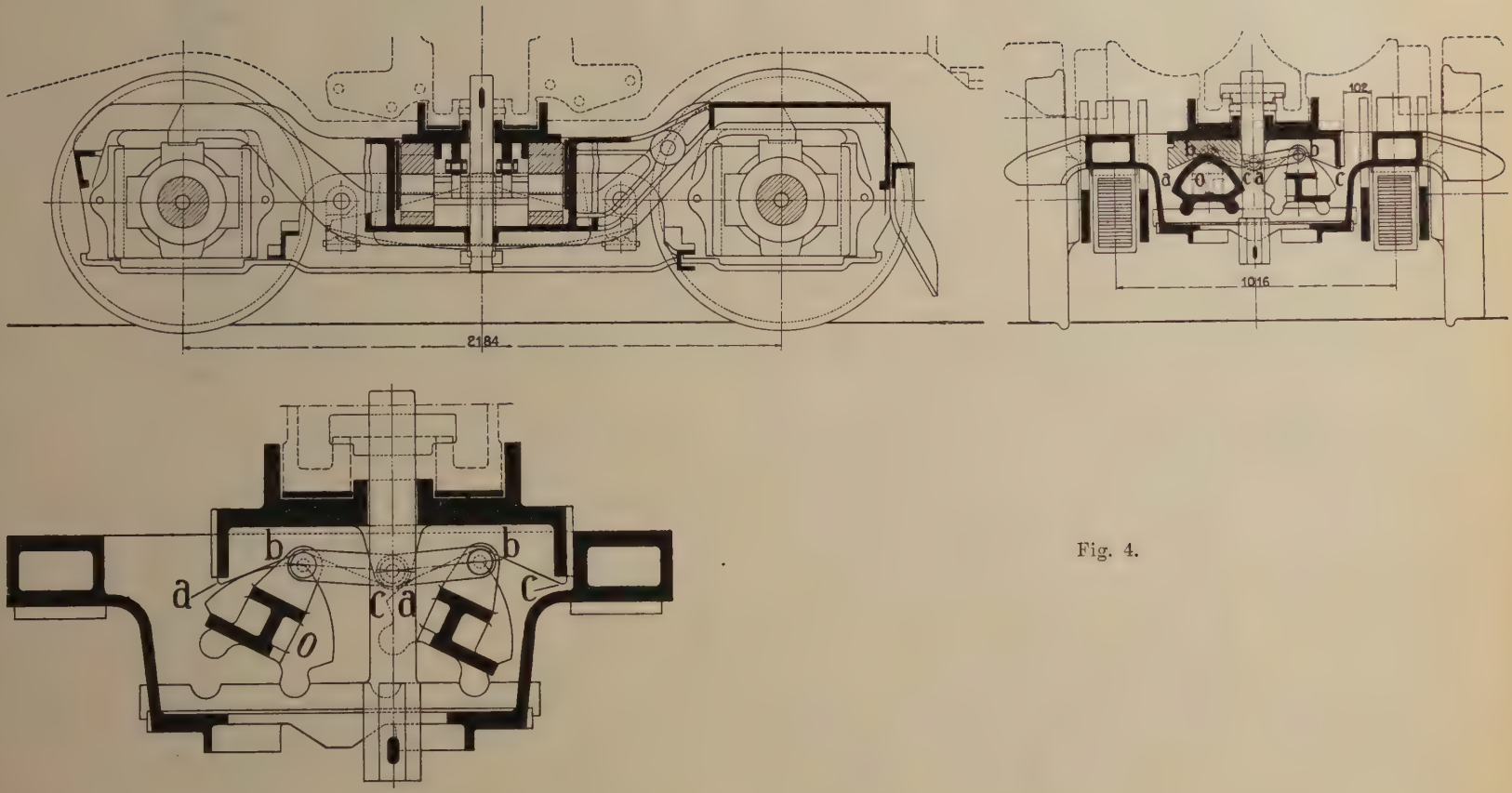


Fig. 4.

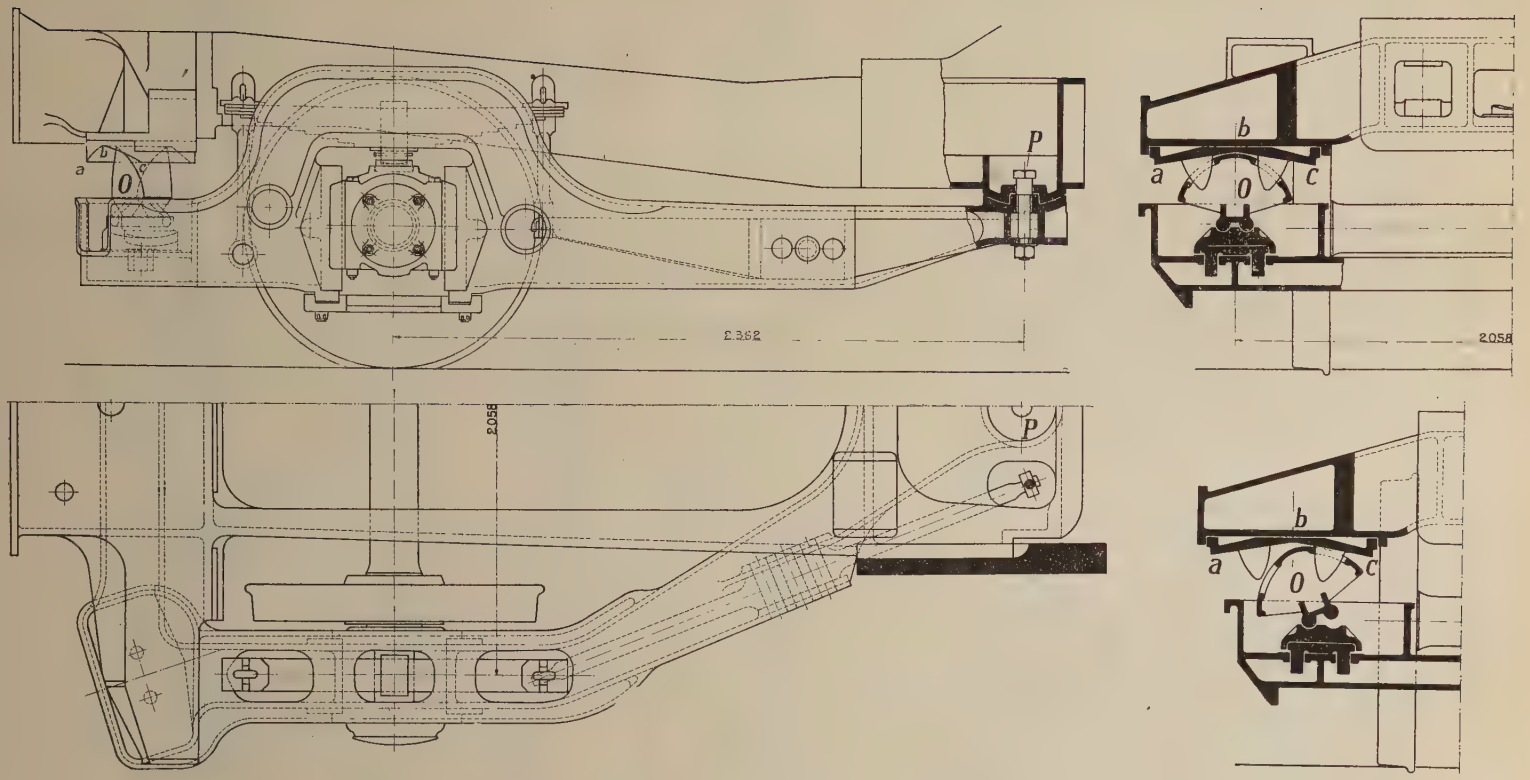


Fig. 5.

of balancing, as given in his book « The Balancing of Engines », to ascertain the part of the connecting rods to be taken as rotating, 10 % of the cross couple set up by the reciprocating parts was balanced, and 26 % of the longitudinal couple set up by the same parts. Although so small a proportion has been balanced, the result has been quite satisfactory.

Motion.

The cast steel cylinders have been cast to the same specification as the steel used in other vital parts of the frame, namely steel to be melted in an electric furnace and to have a tensile strength of 50 to 55 kgr./mm² (31.75 to 34.9 Engl. tons per sq. inch), with not less than 20 % elongation. This practice, in general use in America, cross-braces the frame much more rigidly at the front end, and when needed repairs can be done easily by welding. The drawback is the much higher cost. The designs also show traces of American practice.

The cylinders are fitted with a French automatic by-pass with valves at the front and back ends, coming off their seats when the regulator is shut and thereby opening the large pipe connecting the two ends of the cylinder.

The ratio of the average tractive effort

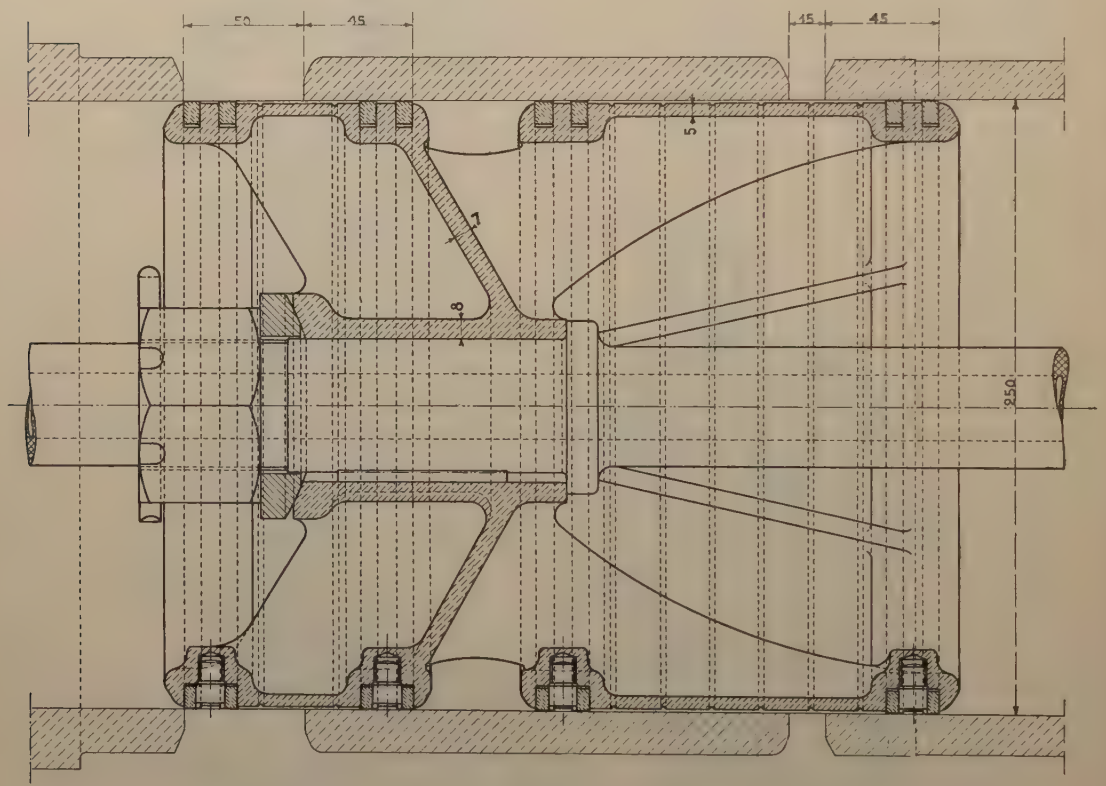


Fig. 6.

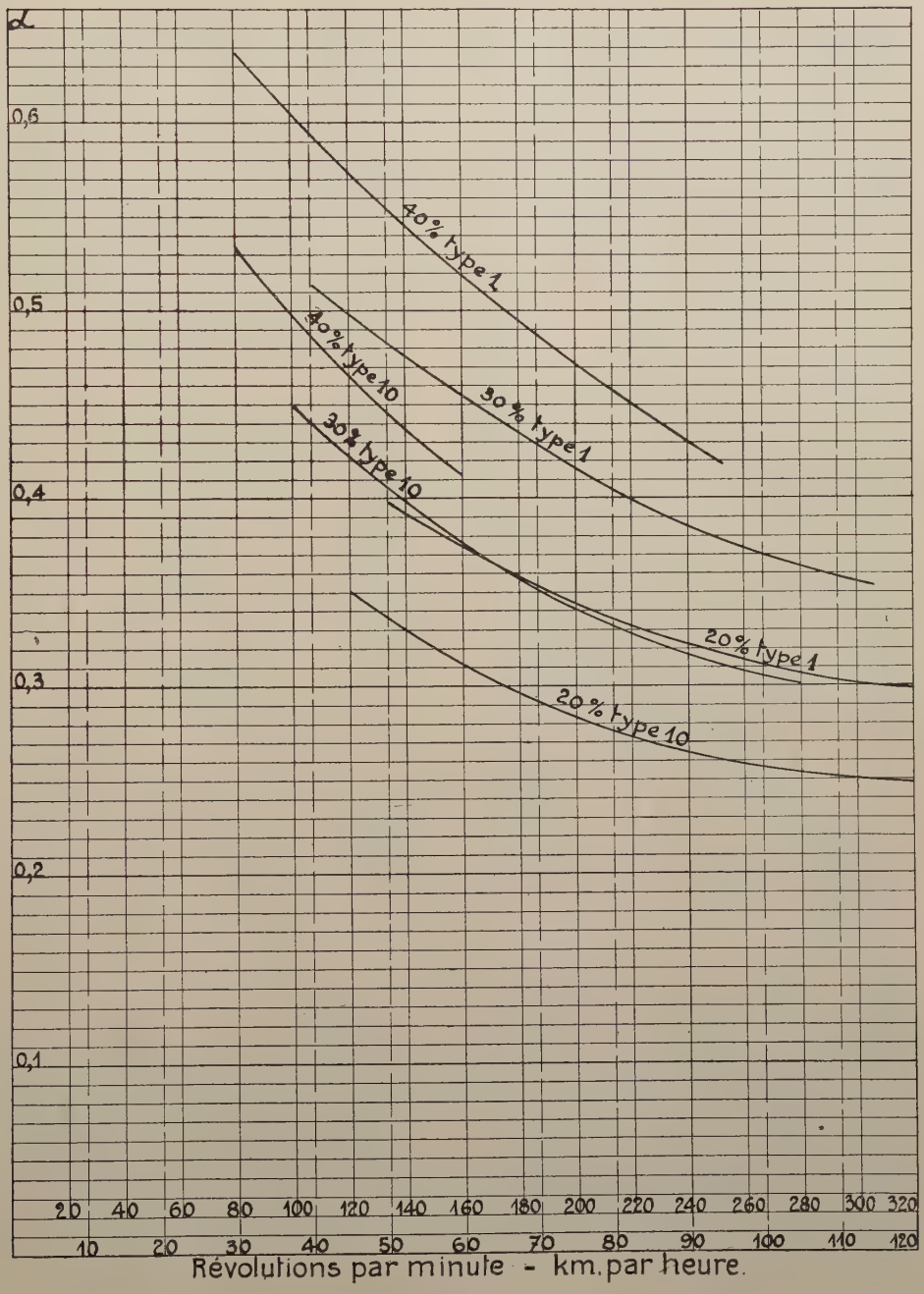

α
0,6
0,5
0,4
0,3
0,2
0,1
40% type 1
40% type 10
30% type 1
30% type 10
20% type 1
20% type 10
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
10 20 30 40 50 60 70 80 90 100 110 120
Révolutions par minute - km. par heure.

Fig. 7.

at starting to the adhesive weight, calculated by the usual formula

$$\frac{T}{A} = \frac{1}{A} \frac{2 \times 0.75\ p\ d^2\ L}{D}$$

p, d, L and D being the boiler pressure, cylinder diameter, piston stroke and the driving wheel diameter respectively, is :

$$\frac{17\,319}{72\,000} = \frac{1}{4.15}$$

Particular attention has been devoted to the steam flow especially through the valves, the most difficult matter, especially at early cut-offs and at high speed. This was more marked in the type 1 locomotives, designed with piston valves in place of poppet valves. The problem, however, was very successfully solved by the double-ported valve of figure 6, with narrow rings.

The calculated evaporative capacity is 16 475 kgr. (36 945 lb.) per hour by COLE's method for a coal consumption of 585 kgr. per sq. metre (120 lb. per sq. foot) of grate per hour. The trials showed 16 700 kgr. (36 815 lb.). At maximum speed and 385° C. (725° F.) superheat, this capacity corresponds to a certain cut-off in the cylinder, the optimum value. With this superheat, speed and cut-off, the maximum port opening gives an instantaneous steam speed of about 20 m. (65.6 feet) per second. The advantage of so low a speed relatively to that found on many comparable locomotives is confirmed by the small drop in pressure during admission revealed by the indicator diagram.

The ports are fully opened during exhaust and with an absolute pressure of 1.2 kgr./cm² (17 lb. per sq. inch) and a residual superheat of 125° C. (207° F.), the instantaneous speed is only 57 m. (187 feet) per second.

The indicator cards also show that the pre-admission, pre-exhaust, and compression points are in every way normal in both the inside and outside cylinders, for cut-offs of 15 to 40 % and at speeds of 50 to 120 km. (31 to 75 miles) an hour. The curves of figure 7 show how well the cylinders and valve gear of the new locomotive have been designed.

These curves give the variation in the values of the actual to the calculated power $\frac{2\,p\,d\,2\,L}{D}$ at full admission and are characteristic of full diagrams at given cut-off and speed. The same diagrams of the old *Pacific* engine, reproduced for comparison, show how much better the new engine is.

Screw reversing gear is fitted with a non-automatic double compressed-air servo-motor acting on a lever keyed on the weigh-bar shaft.

Brake.

The locomotive is fitted with the automatic and direct Westinghouse brake acting on both the bogie and coupled wheels.

The bogie is braked by a 305-mm. (12 inches) diameter horizontal cylinder fastened to a centre bracket at the forward end of the monoblock frame, the push rod acting on a vertical return crank.

The coupled wheels are braked by two 355-mm. (14 inches) diameter horizontal cylinders with a piston stroke of 127 mm. (5 inches) carried on a cross stay immediately in front of the intermediate coupled axle. The total braking power is 45 840 kgr. (101 060 lb.) or 64 % of the adhesive weight. The brake gear leverage is 6.6 to 1.

A cross-compound air pump is fitted, controlled by a S. G. 4 regulator which maintains a constant predetermined pres-

sure in the main reservoirs between any release and the succeeding application, and increases this pressure during the application of the brake, so as to give a powerful rush of air into the train pipe when releasing. The control of the pump by the S. G. 4 regulator is conjugated with that of the H 7 driver's valve when the latter's handle, placed in one of the three last positions (neutral, service application, emergency application) operates the excess pressure valve of the regulator.

Other equipment.

The locomotive is fitted with train steam heating equipment. A speed recorder is fitted. Compressed air sanders are provided on the coupled wheels. A soot blower is fitted. The engine and tender are lighted by a turbo-generator.

The superheater elements and the cylinders are cooled when running with the regulator shut off by admitting steam into them through a snifting valve.

The cylinders are lubricated by a mechanical lubricator with an anti-caboniser. A mechanical lubricator with separate feeds is used to lubricate the coupled axle boxes and has proved most effective. Auxiliary oil boxes have, however, been fitted for use should the mechanical lubricator fail.

Side screens have been fitted at the front end of the locomotive to lift the smoke.

* * *

Type 1 tender.

The type 1 tender is carried on two four-wheeled bogies with 1 m. (3 ft. 3 3/8 in.) diameter wheels.

This small diameter was selected to keep the tractive and buffing forces in the plane through the horizontal centre line of the frame, as better results are obtained than when these forces do not act through this centre plane, and the frame is stronger for equal weight. This

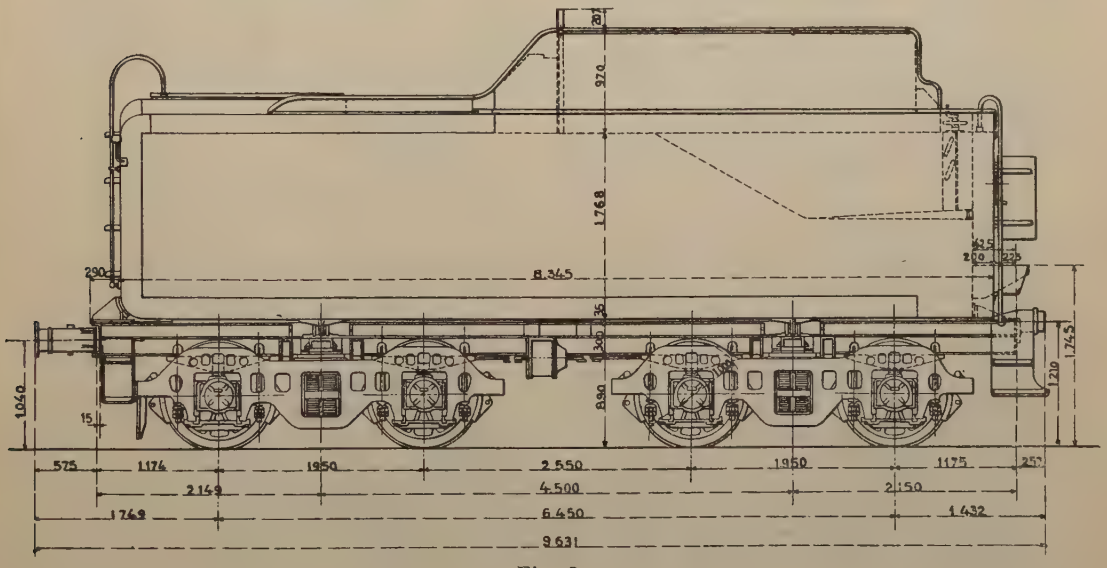


Fig. 8.

involves the use of improved axle boxes to avoid such risk of hot boxes as may be expected with ordinary oil boxes. Self-aligning double-row roller bearing axle boxes were therefore fitted.

The bogie wheel base is 1.95 m. (6 ft. 4 13/16 in.) and the centres are 4.50 m. (14 ft. 5 3/16 in.) apart.

Figure 8 gives the general layout of this tender which contains 38 m³ (8 360 Br. gallons) of water, and carries 10.5 m³ (370 cu. feet) of fuel.

The tank is to the same design as on the tenders of the Belgian *Mikado* locomotives and is fastened to the frame by four sets of side holding-down gear incorporating longitudinal spring dampers. Two safety stops are fitted at the front and back ends to prevent the tank slipping. Four side blocks fitted with 3-mm. (1/8 inch) clearance when the tender is on the level, prevent the tank going over too far when on superelevated track.

The bottom tank plates are 8 mm. (5/16 inch) thick, the sides 6 mm. (1/4 inch) thick, and the top 5 mm. (3/16 inch). It is 2.86 m. (9 ft. 4 5/8 in.) wide and 2.10 m. (6 ft. 11 in.) high.

The main framing of the tender tank consists of two longitudinal girders, the same depth as the tank, cross-braced by 9 cross stays. They are built up of rolled sections fastened to 6-mm. (1/4 inch) thick plates which form the webs.

The weight of the tank and its fitings is 12.5 t. (12.3 Engl. tons). The shovel plate is 400 mm. (15 3/4 inches) above the cab floor.

The frame consists of four longitudinal members connected by cast steel drag boxes and three cross stays built up from rolled sections. 140 × 60 × 7 mm. (5 1/2 in. × 2 3/8 in. × 9/32 in.) channels forming double diagonals cross brace the inside longitudinals which are formed of 300 × 75 × 9 mm. (11 13/16 in. × 2 61/64 in. × 3/8 in.) channels. Two wide flanged 140 × 140 × 8 mm. (5 1/2 × 5 1/2 in. × 5/16 in.) beams are used for the outside frames. The complete frame weighs about 6 1/2 tons and is carried on the bogie through spherical centres.

The monoblock cast steel bogie frame shown in figure 9 weighs 2 150 kgr. (4 740 lb.), the sole bars, cross bar, headstocks and bolster being tubular in section.

The tender is fitted with double spring gear; the first consists in laminated springs on each of the roller-bearing axle boxes. The springs have ten 120 × 13 mm. (4 23/32 in. × 33/64 in.) grooved plates 0.82 m. (32 1/4 inches) between centres of hangers and having a flexibility of 2.66 mm. (0.11 inch) per ton. This first suspension is completed by eight full elliptical springs, each separate spring having ten 120 × 13 mm. (4 23/32 in. × 33/64 in.) plates, 0.72 m. (28 3/8 inches) long. The flexibility of the full elliptical spring per ton is 2 × 1.77 mm. (2 × 0.07 inch). The combined flexibility per ton is therefore 6.2 mm. (0.25 inch).

The total deflection under load is consequently :

$$\frac{48}{8} \times 6.2 = 37.2 \text{ mm. } (1 \frac{29}{64} \text{ inches}).$$

This deflection is the same as on the Belgian bogie tenders known as the « American tenders », which carry 21.5 and 31.5 m³ (4 830 and 6 930 Br. gallons) of water respectively.

The tare weight of the tender, as built, was 35 335 kgr. (77 900 lb.).

This tender is fitted with the automatic and direct brake. Each wheel is braked by two blocks, the brake gear being self-compensating. A double-acting slack adjuster fitted maintains the correct gap

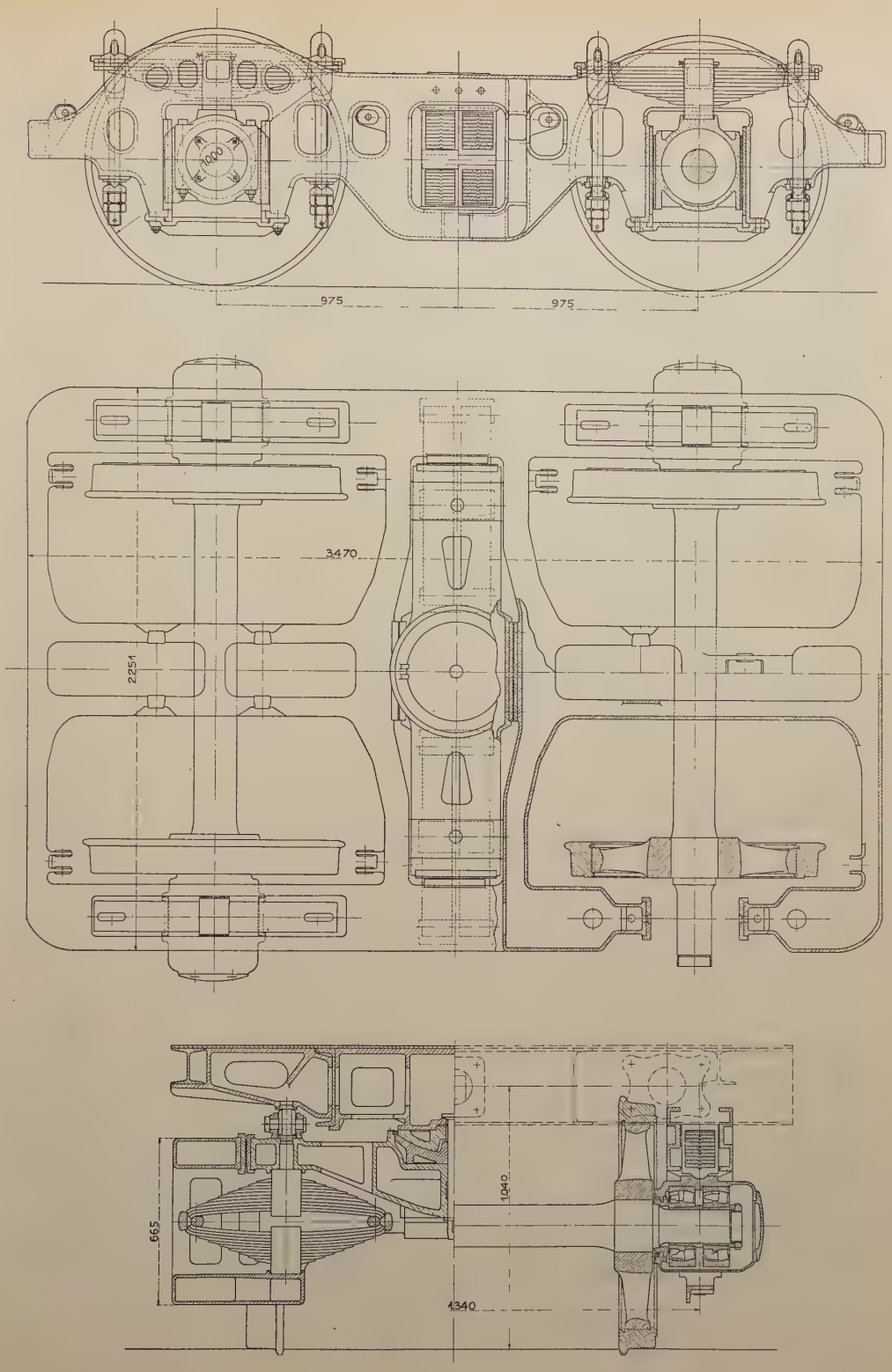


Fig. 9.

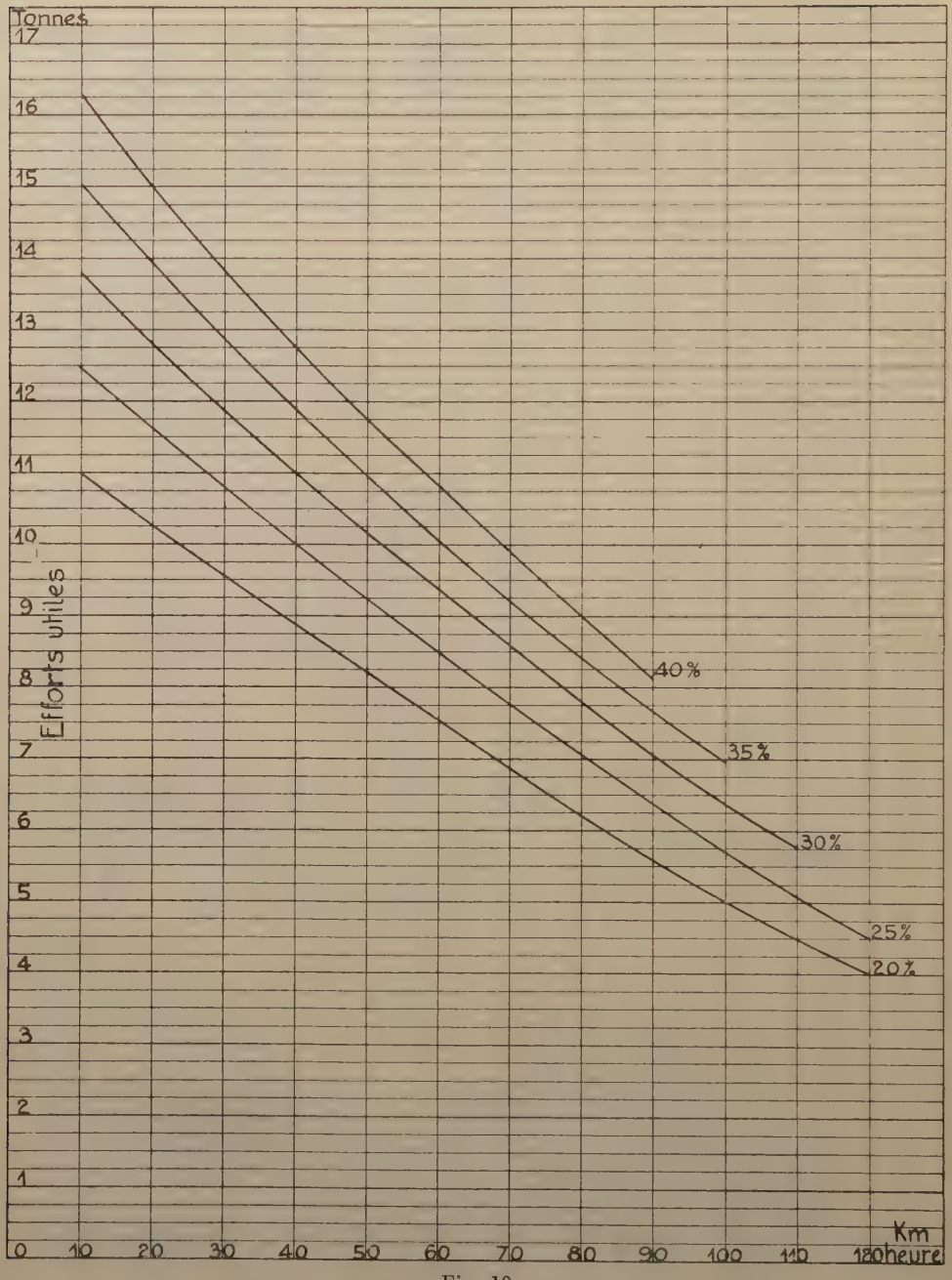


Fig. 10.

Note: Efforts utiles = Drawbar pull.

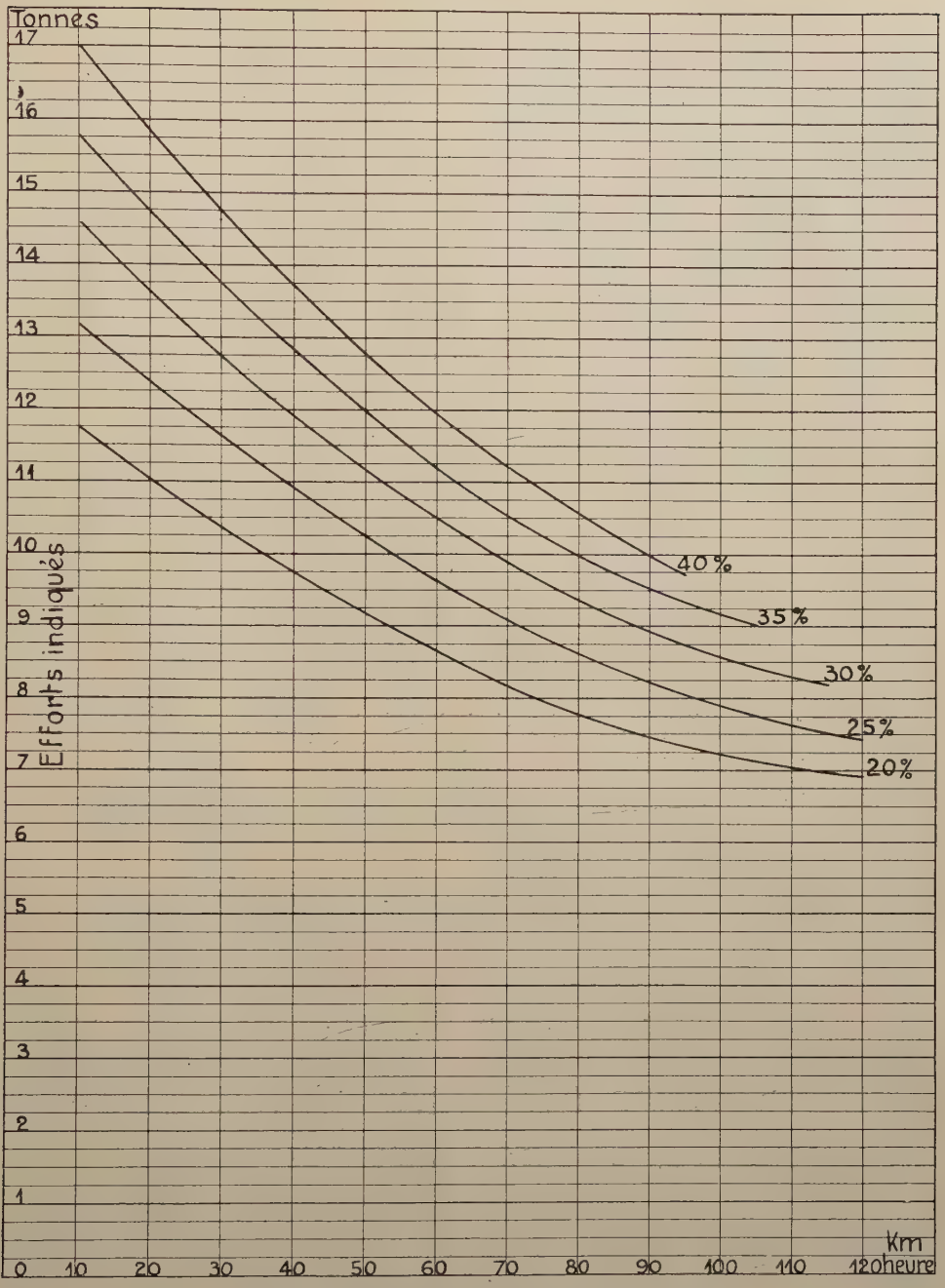


Fig. 11.

Note: Efforts indiqués = Indicated tractive force.

between the brake blocks and the wheels, increasing or reducing it as necessary, by a coarse-threaded screw, the adjuster being operated by the pull set up when applying the brake, unscrewing the screw on the brake coming off.

A single 355-mm. (11 ft. 7 25/32 in.) diameter brake cylinder exerts a theoretical pull of 3 460 kgr. (7 630 lb.); the leverage is 9.1 to 1; 90 % of the tare weight is therefore braked. The pressure per block is 1 970 kgr. (4 345 lb.) and the specific pressure 5.5 kgr./cm² (78.2 lb. per sq. inch.). The screw hand brake, when a manual effort of 24.5 kgr. (54 lb.) is exerted on the brake wheel, gives the same braking power.

* * *

Dynamometer-car trials.

No. 101, the first of these locomotives, has undergone dynamometer car trials working special fast trains with heavy loads; the engine showed itself well able to do the work it was built for.

On the level a speed of 118 km. (73.3 miles) an hour was maintained, hauling 16 bogie vehicles, with a total tare weight of 615 t. (605 Engl. tons), and also up a 1 in 526 gradient. On a continuous 1 in 250 gradient, the engine maintained a speed of 100 km. (62 miles) an hour with a load of 505 t. (497 Engl. tons) behind the tender; it also maintained a steady speed of 70 km. (43.5 miles) an hour on a continuous 1 in 62 gradient.

The following table gives the general results of the dynamometer-car trials carried out on the 8th April, 1935, from Schaerbeek to Ostend and back, the highest point of the line being 30 m. (98 1/2 feet) above the starting point and 40 m. (131 feet) above the arrival station.

Tare weight of vehicles hauled	615 t.	*(605 Engl. tons)*
Distance (outward and return run)	231.6 km.	*(143.8 miles)*
Booked time	158 minutes	
Actual time	151 minutes	
Time regulator open	121.4 minutes	
Useful work	3 505 H.P./hour.	
Indicated work	5 430 H.P./hour.	
Average draw-bar H.P. with regulator open	1 730	
Indicated draw-bar H.P. with regulator open	2 680	
Total fuel used	5 775 kgr.	*(12 730 lb.)*
Average coal consumption per draw-bar H.P./hour	1.645 kgr.	*(3.625 lb.)*
Average coal consumption per indicated H.P./hour	1.062 kgr.	*(2.341 lb.)*
Total water used	36.5 m³	*(8030 Br. gall.)*
Average evaporation per pound of coal	6.3 lb.	

The superheat was about 365° C. (689° F.) soon after opening the regulator, the working temperature being 375 to 385° C (707 to 725° F.) — 410° C. (770° F.), the maximum being reached several times. The temperature of the gases leaving the flues fluctuated between 310 and 330° C. (590 and 626° F.), and at the smoke box end of the smoke tubes between 330 and 350° C (626 and 662° F.). The vacuum in the smoke box was 150 to 250 mm. (6 to 10 inches) of water and the analysis of the combustion gases gave a CO^2 content of 11.2 %. The back pressure at full load rarely exceeded 300 grammes per cm² (4.26 lb. per sq. inch).

During a trial run between Schaerbeek and Ans, on which 562 kgr. of coal were burnt per hour per sq. metre (115 lb. per sq. ft.) of grate and 71 kgr. of water evaporated per hour and per sq. metre

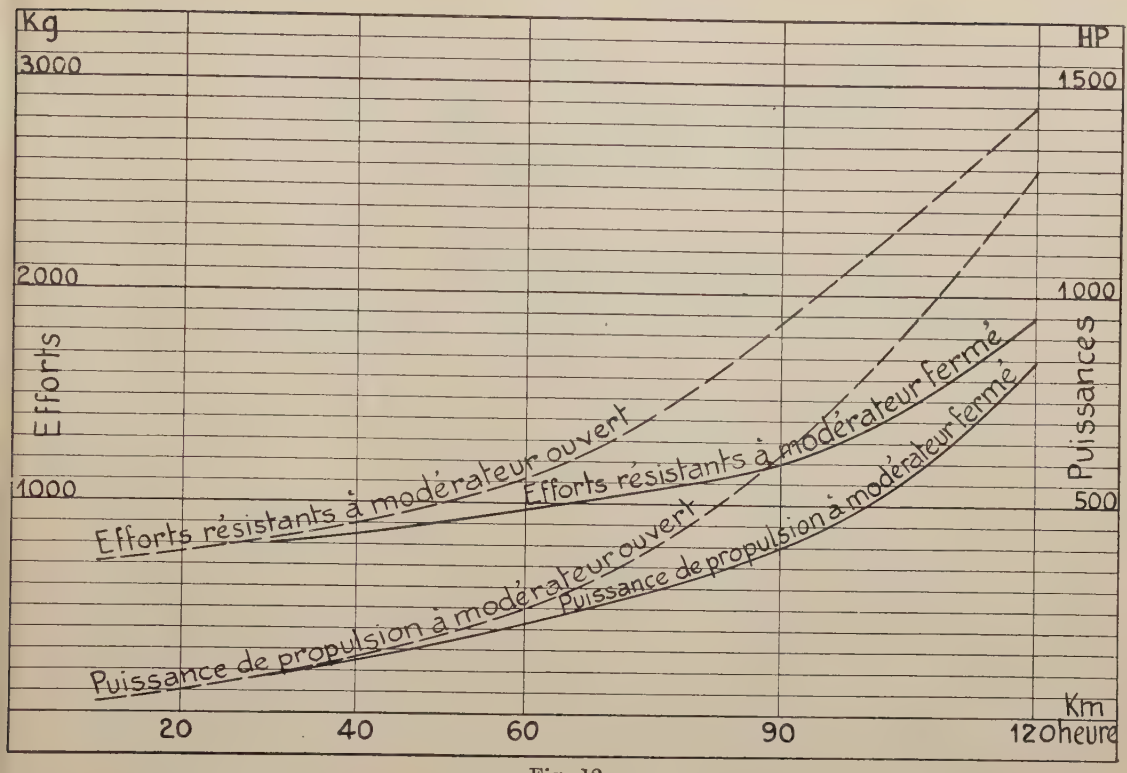


Fig. 12.

Explanation of French terms:

Efforts résistants à modérateur ouvert (fermé) = Resistance with regulator open (closed). — Puissance de propulsion à modérateur ouvert (fermé) = Tractive power with regulator open (closed). — Puissances = Horse-power.

(14.5 lb. per sq. ft.) of heating surface, the average indicated horse-power developed was 2 700 at the average speed of 96 km. (59.7 miles) an hour. The end of the run is 159 m. (522 feet) above the departure station; the line is on a 1 in 250 rising gradient for a distance of 30 km. (18.6 miles).

A number of tests were made in addition to ascertain the drawbar and indicated horse-power at various cut-offs and at the usual speeds; the results are shown in diagrams 10 and 11. Finally the running resistance of the locomotive and tender at different speeds, with open and closed regulator, were also measured by means of the dynamometer car and are shown on the diagram, figure 12, which also shows the corresponding tractive power developed.

To conclude, this simple-expansion *Pacific* type locomotive, with an adhesive weight of 72 t. (70.9 Engl. tons), has been found able to develop continuously a drawbar horse-power of 2 700 corresponding to an indicated horse-power of 3 400, and to haul on the level trains of 700 t. (689 Engl. tons) at a sustained speed of 120 km. (75 miles) an hour.

[656. 222.1]

Note on Train Speeds,

by Lionel WIENER,
Professor at the University of Brussels.

PART II *(Continued)* [1]

Train speeds and services in different countries.

XIV. — POLAND.

SUMMARY.

CHAPTER XLIII.

1. General.
   Gradients.
2. The railway system.
   Track and loading gauges.
3. International services.
   Cross-Warsaw services.
   Frontier lines.
4. Alternative routes.
5. Traction.
   Electric traction.
   Railcars.
   Steam locomotives.
6. Speeds.

CHAPTER XLIV.

The International Sleeping-Car Company in north-eastern Europe.

1. Polish sections of International Sleeping-Car Company services.
2. 1.52-m. (5′) gauge rolling stock in the Baltic States.
3. The Company's Russian services.

APPENDIX.

Wagons running on standard and Russian gauges.

CHAPTER XLIII.

XLIII-1. — General. — The Polish railway system, which is of very unequal density, includes four important centres : Warsaw, Poznan, Lwow, and the Katowice-Krakow district. The lines radiating east of Warsaw run for very long distances and already show the characteristics of the flat-country railways of Eastern Europe, whereas towards the western frontiers the system is similar to those of western Europe.

Southern Poland alone is hilly, hence interesting mountain lines south of the Krakow-Lwow-Stanislawow railway. Although the eastern Carpathians form the Czechoslovak frontier, seven railway lines cross them at over 800 m. (2 625 feet) above sea level, while the moun-

(1) Cf. *Bulletin of the Railway Congress*, October and November 1933; January, May, June and July 1934; February, March, April, May, July and October 1935; March 1936.

tains themselves are more than 2 000 m. (6 560 feet) high (1).

The frontier range rises very rapidly in the east to a height of 1 700 m. (5 600′), [the Babia Göra, south of Makow, is 1 725 m. (5 660′) high], and the lofty Tatry group just south of Zakopane has peaks over 2 500 m. (8 200′) high (2).

In the West, three railways and in the East, the N. Sacz-Kosice railway, cross the mountains, while the line that ends at Zakopane runs slap into it. Finally, further East, four other lines link up Poland and Czechoslovakia.

Most of these railways have gradients reaching 1 in 40 and more. None of the tunnels is 1 km. (0.6 mile) long.

Apart from the main lines, a series of narrow-gauge branches called « forest railways » run into the principal valleys.

XLIII-2. — **The railway system.** — In June 1935, the State Railways operated :

GAUGE	1.435 m. (4′ 8 1/2″).		0.75 m. (2′ 5 1/2″ and 0.60 (1′ 11 5/8″).		Total.	
	Km.	Miles.	Km.	Miles.	Km.	Miles.
Main lines	17 733	11 019	2 448	1 521	20 181	13 140
Secondary track (stations, etc.)	8 175	5 080	...	...	...	...
Branch lines	2 717	1 688	...	...	...	...

These figures include the lines in the Danzig territory as these belong to the Polish Government, besides those of the Port of Danzig Authority, operated by the Polish Railways.

A Germano-Polish Convention, signed at Geneva on the 17th May 1922, turned over to Poland the railways of Upper Silesia, whose mileage has been included in the above figures.

Poland is thus the fifth country in Europe as regards the development of its railway system, which comes after those of Germany, Great Britain, France and the U. S. S. R.

TIMETABLES. — The 1935/36 Winter timetables have been used.

Track- and loading gauges. — Before the war, all main lines save the Warsaw-Vienna standard gauge railway, were built to the Russian 1.52 m. (5′) gauge. Since the reconstitution of Poland, the standard 4′ 8 1/2″ European gauge has been adopted and all essential conversions made. The field of utilisation of the standard gauge was therely extended, as it now includes the Russo-Polish provinces, and has made its way into Latvia, where it runs some distance beyond the

(1) The frontier itself, to the east of the last of these lines, is marked by a series of high peaks : the Howeria (2 058 m. = 6 750′), the Gutin Tomnatsk (2 008 m. = 6 590′), the Pop Iwan (2 026 m. = 6 650′). Further on, the frontier between Poland and Rumania also follows the crest line, but the mountains are lower, reaching from 1 700 to 1 800 m. (5 600′ to 5 900′) only.

(2) The Hysy is 2 503 m. (8 200′) high; the Gierlach, 2 663 m. (8 740′). Both are just beyond the frontier.

frontier, so as to reach several important places.

In the East, the Warsaw-Leningrad railway's track is laid to standard gauge over the whole of the Polish section, to mixed standard and 5′ gauges from the frontier (Zemgale) to Daugavpils, and to the Russian 5′ gauge only, beyond.

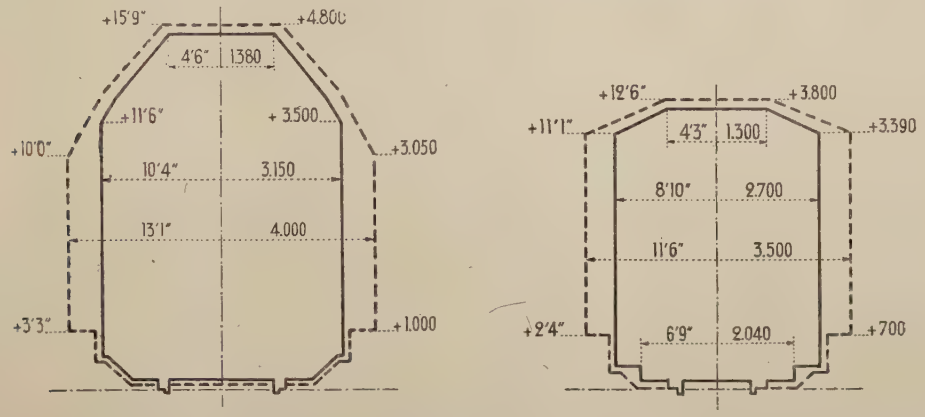


Fig. 266. — Loading gauges for standard and metre-gauge track, Polish State Railways.

In the central and western parts of Latvia, the line from Berlin has been carried on without break of gauge, to the capital, Riga, and to the Latvian port of Liepaja.

For this purpose, the Riga-Jelgava-Gluida-Liepaja railway was built to standard gauge in spite of the new frontier cutting across it so that it includes, between Bengreitene and Vainode, a detour into foreign territory. The standard-gauge line to Berlin branches off this railway at Jelgava, and another standard-gauge railway, which serves the port of Klaipeda, etc. via Keleti (frontier), nearer the coast.

In order to standardise the Latvian system, a broad-gauge line duplicates the standard gauge from Riga to Liepaja, and the Riga-Jelgava-Gluida section has a three-rail track so as to accommodate stock of either gauge.

Together with another frontier section which runs into Latvia at Eglaine so as to shorten the Leningrad line between Zemgale and Daugavpils, these are the only Latvian standard-gauge lines (1).

It should be noted that the fastest train run in this country is between Riga and Jalgava (towards Berlin), the 43 km. (26.7 miles) being covered by ordinary trains in 41 minutes, i.e. at 62.9 km. (39.1 miles) an hour (2).

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(1) Besides two gauges used on the main lines, three other gauges, all narrow ones, are to be found in Latvia, namely :

1.52 m. (5′) gauge	1 746 km. (1 085 miles).
1.435 m. (4′ 8 1/2″) gauge	319 km. (198.2 miles).
1.00 m. (3′ 3 3/8″)	49 km. (30.4 miles).
0.75 m. (2′ 5 1/2″) gauge	312 km. (193.9 miles).
0.60 m. (1′ 11 5/8″) gauge	529 km. (328.7 miles).

(2) It should be added that it takes 36 hours to cover the 910 km. (565.5 miles) between Riga and Moscow, the average speed therefore working out at 26 km. (16.15 miles) an hour.

TABLE 256.

TRACK GAUGE.	Loading gauge.		Constructional gauge.	
	Maximum height.	Maximum width.	Maximum height.	Maximum width.
1.435 m. (4′ 8 1/2″) . .	4.650 m. (15′ 3″)	3.150 m. (10′ 4″)	4.800 m. (15′ 9″)	4.400 m. (14′ 5 1/4″
1.00 m. (3′ 3 3/8″) . .	3.800 m. (12′ 5 5/8″)	2.700 m. (8′ 10 5/16″)	3.900 m. (12′ 9 9/16″)	3.500 m. (11′ 6″)
0.75/0.76 m. (2′ 5 1/2″ — 2′ 5 7/8″) . . .	3.300 m. (10′ 10″)	2.600 m. (8′ 6 11/32″)	7.400 m. (24′ 3 11/32″)	3.400 m. (11′ 2″)
0.60 m. (1′ 11 5/8″) . .	3.200 m. (10′ 6″)	2.500 m. (8′ 2 7/16″)	3.300 m. (10′ 10″)	3.300 m. (10′ 10″)

The narrow-gauge lines are laid either to the 0.75-m. (2′ 5 1/2″) (1), to the 0.76-m. (2′ 5 7/8″) or to the 0.60-m. (1′ 11 5/8″) gauge. There are also a few 0.785-m. (2′ 7″) gauge lines.

XLIII-3. — International services. — Téese services were necessarily much affected by the War, the Berlin-Petrograd line being most affected as it now crosses the Polish Corridor for 97 km. (60.3

(1) The *Lithuanian Railways* 0.75-m. (2′ 5 1/2″) gauge rolling stock, include 0-10-0 locomotives, built in 1935 by the Skoda Works, in which the centre line of the boiler has been raised to a height of 2.30 m. (7′ 6 1/2″) above rail level thus providing a grate able to cope with the poor coal used. Their leading dimensions are as follows :

Cylinders	450 mm. × 450 mm.	(29 11/16″ × 29 11/16″)
Diameter of boiler	1.228 m.	(4′ 23/64″)
Length of tubes	4.000 m.	(13′ 1 1/2″)
Heating surface :		
Firebox	6.50 m²	(70 sq. ft.)
Tubes	70.00 m²	(753 sq. ft.)
Total	76.50 m²	(823 sq. ft.)
Superheater	23.00 m²	(247.6 sq. ft.)
Grate area	1.80 m²	(19.4 sq. ft.)
Boiler pressure	14 kgr./cm²	(199 lb. per sq. in.)
Overall height	3.300 m.	(10′ 10″)
Diameter of wheels	0.900 m.	(2′ 11 1/2″)
Wheel base total	4.200 m.	(13′ 9 23/64″)
Wheel base rigid (I-IV)	3.150 m.	(10′ 4″)
Weight in working order	37.5 t.	(37.0 Engl. tons)
Tender diameter of wheels	0.724 m.	(2′ 4 1/2″)
Tender wheelbase	4.370 m.	(14′ 4″)
Tender water capacity	11 m³	(2 420 Br. gall.)
Tender fuel	9 m³	(318 cu. ft.)
Tender weight in working order	25.5 t.	(25.1 Engl. tons)
Locomotive and tender :		
Total wheelbase	11.900 m.	(39′)
Total length	15.555 m.	(55′ 7/16″)
Total weight	65.5 t.	(64.4 Engl. tons)

In order to facilitate running through curves of 60-m. (3 chains) radius, with 20 mm. (25/32″) superelevation, the 5th pair of wheels have a side play of 15 mm. (19/32″) on either side, and the thickness of the flanges on the second pair of wheels is 5 mm. (13/64″) less than on the others.

These locomotives haul 300-ton trains up 1 in 62 gradients through curves of 200 m. (10 chains) radius at 20 km. (12.4 miles) an hour, and 450-ton trains up 1 in 200 gradients at 40 km. (25 miles) an hour.

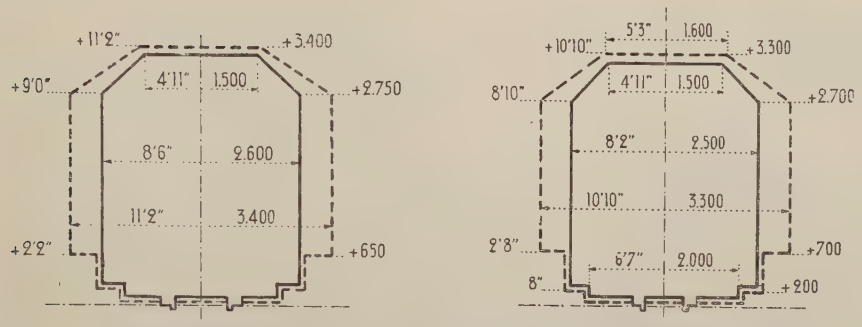

Fig. 267. — Loading gauges for 0.75-m. and 0.60-m. (2′ 5 1/2″ and 1′ 11 5/8″) track, Polish State Railways.

miles) between Chojnice (320th km. = 199th mile from Berlin) and Tczew (417th km. = 259th mile); the next 18 km. (11.2 miles) between Tczew and Malbork (Marienburg), 444th km. (276th mile) lie in Danzig territory and lead to the frontier of East Prussia.

As many as 23 Germano-Polish railway lines have been closed down in the frontier regions, a few international lines only being used by « privileged trains », the composition of which was laid down by the Treaty of Versailles (clauses 89 and 98), and confirmed by the supplementary agreement of the 21st April 1921, which allowed of a few other lines to be reopened. A new arrangement of the 14th February 1933 further relaxed some of these conditions.

Beyond Malbork, the Berlin-Petrograd railway ran through the frontier towns of Eydtkuhnen (740th km. = 459.8th mile) and Wirballen (742nd km. = 461th mile) to Wilno (936th km. = 582nd mile), but this line also has been cut and there is a gap of 62 km. (38.5 miles) between the Lithuanian station of Kaunas and the Polish station of Zawiasy, which lies 42 km. (26.1 miles) from Wilno. The distance between Kaunas and Wilno was formerly 97 versts (64.3 miles) and another 658 versts (436.3 miles) on to Petrograd.

Before the War, this was the longest Russian non-stop run, accomplished in 108 minutes at an average speed of 57.5 km. (35.7 miles) an hour.

The crack trains now continue from Kaunas (829th km. = 515th mile) to Riga (1 123rd km. = 699th mile) where the 4′ 8 1/2″ gauge track ends.

On the other hand, trains from Berlin to Petrograd follow the Berlin-Warsaw (567th km. = 352nd mile from Berlin Schl.), Bialystok, Wilno (990th km. = 615th mile), Turmont (1 138th km. = 707th mile) and Petrograd route.

Between the Warsaw Central station, where most trains particularly those from the south and west arrive, and the Eastern station, the trains follow the northern half of the inner circle, the southern the terminus of the eastern lines, section of which it is proposed to build. However, the electrification of the outer-suburban radiating lines provides for the opening out of two termini which would be connected by a direct 7.5-km. (4.7 miles) S. W.-N. E. line crossing the Vistula in the very heart of the town. (fig. 268).

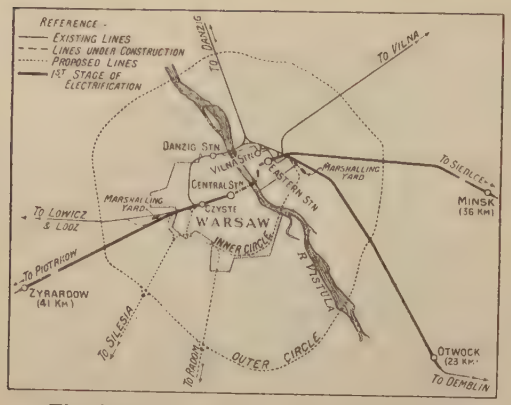

Fig. 268. — Railways through Warsaw (1).

FRONTIER LINES. — As elsewhere, the peculiar features due to the new and often original layout of the frontiers as laid down by the Treaties are to be found in Poland and in this instance. these are complicated by the existence of the free town of Gdansk (Danzig) (2).

XLIII-4. — **Alternative routes.** — It has been necessary, owing to the need of merging into a single system the odd ones found in present Poland, to build more than 1 500 km. (930 miles) of new railways. Some of them complete the old system, while others are cut-offs giving alternative routes between certain places.

The most important by-pass is of course that between Kutno and Poznan (178 km. = 110.6 miles) on the Warsaw-Berlin international line, which avoids the 250-km. (155 miles) roundabout Torun route.

More recently, a new location improved the Warsaw-Krakow line, at either end; this was opened to traffic in October 1934 and included both the Warsaw-Radom (102.8 km. = 63.9 miles) and the Miechow-Krakow (51 km. = 31.7 miles) by-passes which have shortened the journey from 364 to 320 km. (226.2 to 199 miles).

TABLE 257.

POLISH ALTERNATIVE ROUTES.

FROM WARSAW GL. to	Distance. Km.	Distance. Miles.	Via	Distance. Km.	Distance. Miles.	Via
Laskowice (Gdingen) . .	278	172.7	Dzialdowo.	447	277.8	Kutno.
Posen (Berlin)	304	188.9	Kutno.	390	242.3	Ostrow.
Krakow.	364	226.2	Czestochowa.	320	198.8	Radom.
Kowel	335	208.2	Lublin.	339	210.7	Siedlice.
Stolpce	468	290.8	Bialystok.	487	302.6	Do.
Wilna	423	262.8	Do.	...	...	Do.

(1) This illustration is taken from *The Railway Gazette*.

(2) The following are the lengths of the sections of railway between the two respective frontier stations :

Zbaszyn-Neu Bentschen	6 km.	(3.7 miles).
Deutsch Eylau (Ilawa) Jamielnik	8 km.	(4.9 miles).
Mariaborg-Tczew (towards Berlin) . . .	18 km.	(11.2 miles).
Strzebielino-Gros Boschpol (towards Berlin)	4 km.	(2.45 miles).
Rawicz-Tracheneerg	13 km.	(8.1 miles).
Zduny-Militsch (towards Breslau) . . .	14 km.	(8.7 miles).

XLIII-5. — **Traction.** — Electric traction. — The Warsaw suburban lines are now being electrified, and it is proposed to extend this electrification to several of the main lines (fig. 268).

Railcars. — The *Polish State Railways* own some fifty railcars which are generally used for local services.

The original fast Austro-Daimler railcars, very similar to the Austrian units

Fig. 269. — Fast Polish railcar, built by the Austro-Daimler Works.

(fig. 269), are used together with other vehicles, for the following services :

Warsaw-Lodz Fab. . . .	3	services daily.
Warsaw-Katowice	1	do.
Katowice-Krakow	2	do.
Krakow-Zakopane	2	do.

Express railcar services are maintained between the Capital, Katowice and Lodz; those to Zakopane are worked over steep gradients. The actual timings do not correspond with those hoped for in the timetable.

Table 258.

RAILCAR SERVICES.

Non-stop runs are shown in **heavy** type.

Route.	Distance. Km.	Distance. Miles.	Time of departure.	Time spent.	Speed. Km./h.	Speed. Miles/h.	Number of stops.	—
Fast (MtE) services.								
Warsaw Gl.-Koluszki-Katowice.	318	197.6	4.00 p. m.	3.35	93.1	57.9	3	205/2206
Warsaw Gl.-Koluszki . . .	105	65.2	**Do.**	1.10	90.0	55.9	...	Do.
Koluszki-Czestochowa . .	125	77.7	5.11 p. m.	1.19	95.0	59.0	...	Do.
Czestochowa-Sosnowiec Pln.	80	49.7	6.31 p. m.	0.53	90.6	56.3	...	Do.
Sosnowiec Pln.	8	5.0	7.25 p. m.	0.10	48.0	29.8	...	Do.
Katowice-Krakow	71	44.1	2.58 p. m.	0.55	77.5	48.2	3	401 2+
Katowice-Mystowice . .	11	6.8	**Do.**	0.08	82 5	51.3	...	Do.
Mystowice-Szozakowa . .	5	3.1	12.39 a. m.	0.09	33.3	20.7	...	Do.
Szozakowa-Trzebinia . .	16	9.9	12.49 a. m.	0.12	80.0	49.7	...	Do.
Trzebinia-Krakow . . .	39	24.2	1.02 a. m.	0.24	97.5	60.6	...	Do.
Krakow-Zakopane	144	89.5	7.29 a. m.	2.47	51.7	32.1	3	501 2+
Krakow Pl.-Sucha	66	41.0	**Do.**	1.04	61.9	38.5	...	Do.
Sucha-Nowy Targ . . .	57	35.4	8.39 a. m.	1.10	48.9	30.4	...	Do.
Nowy Targ-Poronin . .	15	9.3	9.50 a. m.	0.17	52.9	32.9	...	Do.
Warsaw Gl.-Koluszki-Lodz Fab.	140	87 0	10 25 a. m.	1.28	95.5	59.3	...	301 3+

Like several German local railways, the *Lithuanian Railways* use railcars with mechanical transmission which produce their own gas.

The N. A. G. Bussing engines develop 90 H.P. with petrol fuel, and 75 with producer gas. The wood consumption is 250 kgr. per 250 km. (355 lb. per 100 miles) run.

These double-bogie railcars are 16 m. (52′ 6″) long and have 8 second-class and 35 third-class seats, weigh 14 tons empty and can haul one trailer. Their maximum speed is 55 km. (34.2 miles) an hour (1).

FUEL. — Instead of the lignite and other poor fuel formerly used, the Polish locomotives burn coal from the Dombrova and Upper Silesia coalfields.

Its calorific value is sufficient for the *Franco-Polish Railway Company* to have built a « mineral » line, operated since its completion, in March 1933, by the *State Railways*, for the purpose of linking up these mines with the port of Gdynia.

As double heading had to be resorted to with the 4-6-0 locomotives (17 tons adhesive weight per axle) whenever the weight of the expresses reached 500 and 700 tons, new 4-8-2 locomotives, the first *Mountain* type in Europe, were built by the *Cegielski Works*, of Poznan (2); they haul 750-ton loads at the same speeds, with a maximum speed of 100 km. (62 miles) an hour on the level, and 55 km. (34.2 miles) up 1 in 200 gradients. The weight per axle has been increased to 18 tons (fig. 270).

For short services an interesting type of tank locomotive has lately been designed (fig. 271).

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(1) Similar vehicles are used in other Baltic States and in Germany, on the Brandeburg secondary railways.

(2) The leading dimensions of these two types of locomotive are :

	Mountain.		*2-6-2 T.*	
Cylinders	650 × 700 mm.	(25 5/8″ × 27 1/2″)	630 × 700 mm.	(24 3/4″ × 27 1/2″)
Grate area	4.8 m²	(51.7 sq. ft.)	3.8 m²	(40.9 sq. ft.)
Heating surface	238.5 m²	(2 567 sq. ft.)	182 m²	(1 959 sq. ft.)
Superheating surface	86.5 m²	(931 sq. ft.)	66 m²	(710 sq. ft.)
Number of tubes	103 + 26		154 + 40	
Diameter of wheels	0.860 and 1.200 m.	(2′ 9 1/8″ and 3′ 11 1/4″)	0.860 m.	(2′ 9 7/8″)
	1.850 m.	(6′ 13/16″)	1.450 m.	(4′ 9″)
Wheel base rigid	6.000 m.	(19′ 8 1/4″)	3.200 m.	(10′ 6″)
Wheel base total	13.200 m.	(43′ 4″)	11.700 m.	(38′ 4 5/8″)
Weight, empty	104.5 t.	(102.8 Engl. t.)	94 t.	(92.5 Engl. t.)
Do. in working order	113.8 t.	(112.1 Engl. t.)	116.5 t.	(114.8 Engl. t.)
Do. adhesive	72.6 t.	(71.5 Engl. t.)	...	...
Water capacity	32 m³	(7 040 Br. gall.)	10 m³	(2 200 Br. gall.)
Fuel capacity	9 tons		6 tons	

The *Mountain* locomotive is relatively flexible, only the 1st and 4th pairs of wheels being rigid. The 2nd pair have no flanges and the width of their tyres has been increased by 150 mm. (6 inches). The 3rd pair of wheels have a play of 30 mm. (1 3/16 in.) on each side, the bogie centre, like the bissel, a play of 100 mm. (3 15/16 in.) on either side. Their tractive effort is (at 0.65 %) 14 700 kgr. (32 400 lb.).

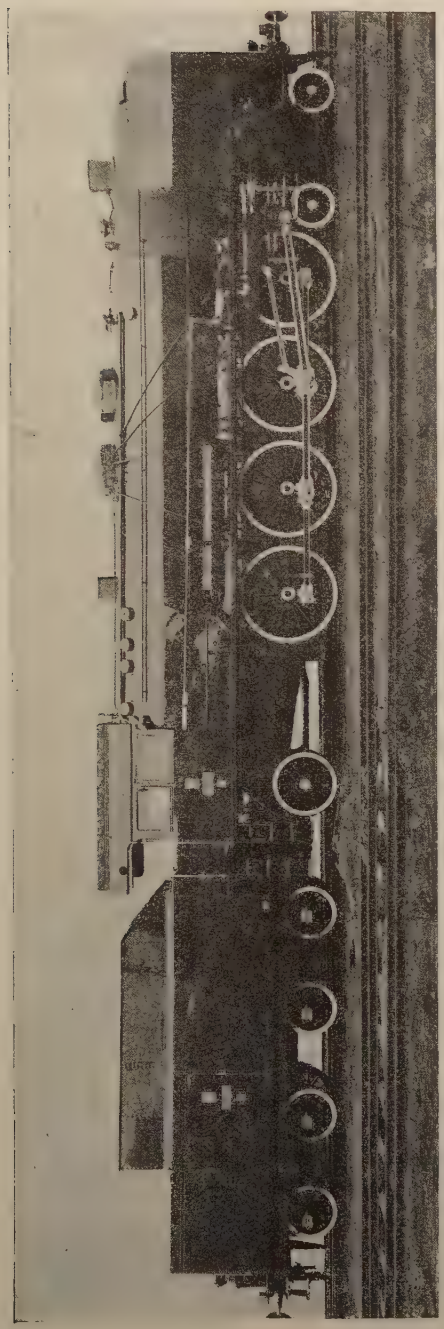


Fig. 270. — 4-8-2 locomotive of the *Polish State Railways*, built by the Gegielski Works, of Poznan.

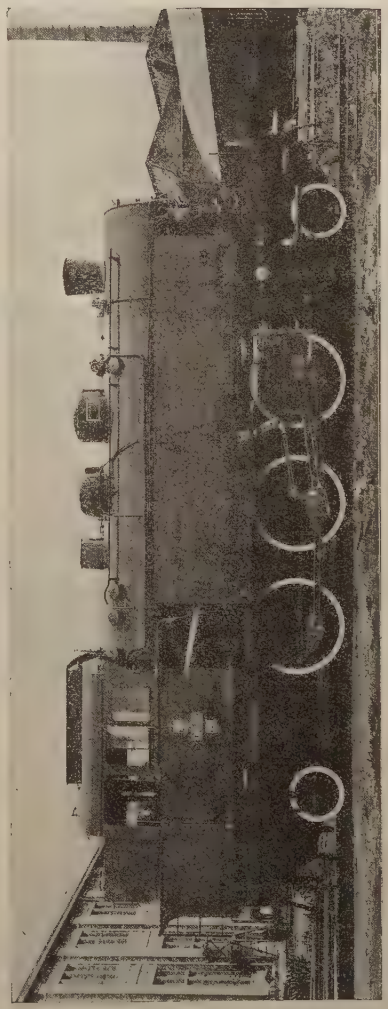


Fig. 271. — 2-6-2 tank engine of the *Polish State Railways*.

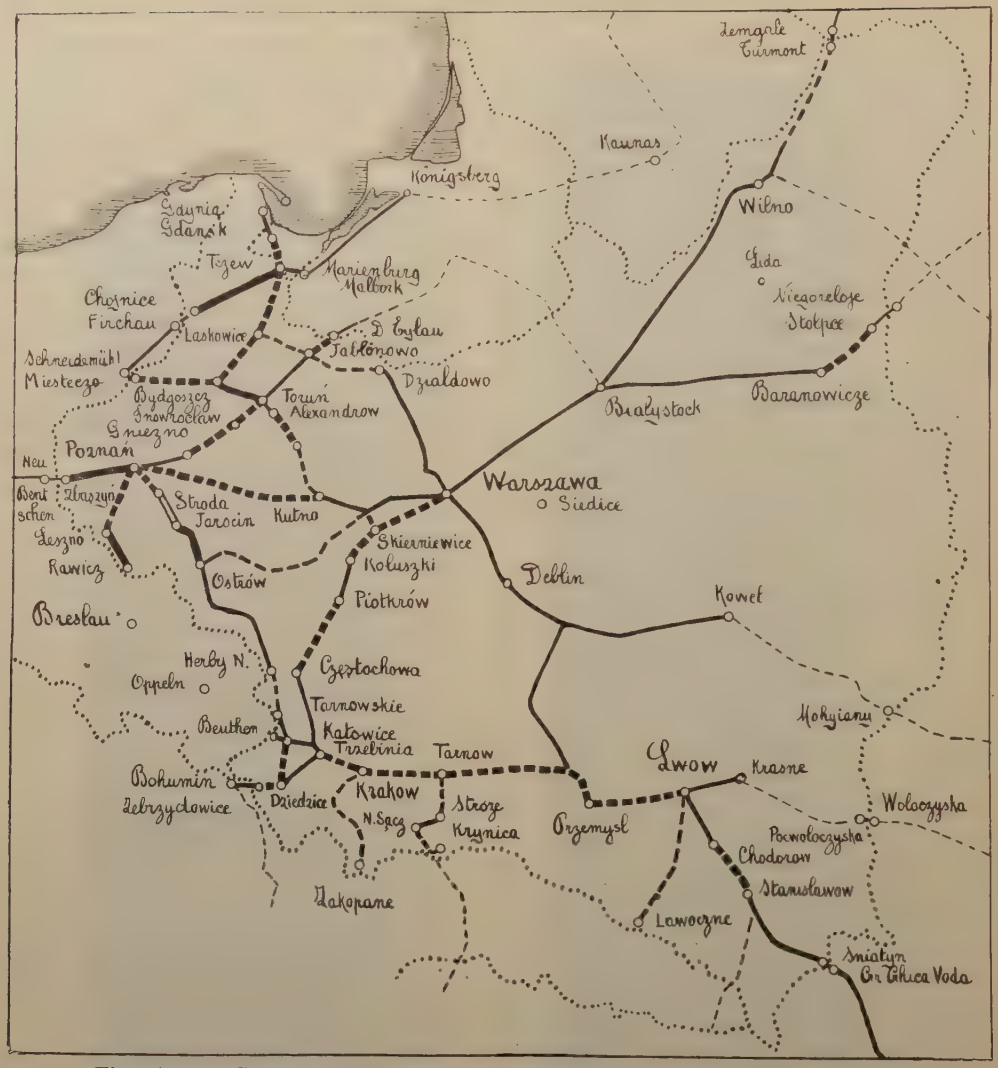


Fig. 272. — Cartogram of maximum overall speeds in Poland (1935 Summer).

XLIII-6. — **Polish train speeds.** — Interesting runs are shown in tables 259 and 260 and maximum overall speeds over the various express lines of the system are shown in the cartogram figure 272.

Out of the 17 459 km. (10 848.7 miles) standard gauge lines :

34 km. (21.1 miles) or 0.2 % are run over at overall speeds of between 90 and 99.9 km. (56 to 61.9 miles) ;

294 km. (182.7 miles) or 1.7 % at overall speeds between 80 and 89.9 km. (50 to 55.9 miles) ;

1 231 km. (764.9 miles) or 7.1 % at overall speeds between 70 and 79.9 km. (44.0 to 49.9 miles) ;

1 699 km. (1 055.7 miles) or 9.7 % at overall speeds between 60 and 69.9 km. (37.5 to 43.9 miles) ;

TABLE 259.

NOTEWORTHY POLISH TRAIN RUNS.

(Non-stop runs are shown in **heavy** type.)

RUN.	Distance		Time of departure.	Time spent.	Speed		Number of stops.	—
	Km.	Miles.			Km./h.	Miles/h.		
Warsaw G.-Jablonowo-Danzig-Gdynia	407	252.9	R11.33 p. m.	7.22	55.2	34.3	11	
Tczew-Laskowice	75	46.6	12.50 a. m.	0 57	78.9	49.0	...	
Warsaw W.-Ciechanow	94	58.4	5.26 a. m.	1.29	63 4	39.4	...	
(Berlin) Chojnice-Malbork (Riga)	115	71.5	4.16 a. m.	1.32	74.0	45 9	1	
Chojnice-Tczew	97	60.3	Do.	1.10	83.1	51.6	...	
Tczew-Malbork	18	11.2	5.35 a. m.	0.17	63.5	39.5	...	
(Berlin, Breslau) Zbaszyn-Poznan-Torun-Ilawa	310	19.3	1.14 a. m.	5.03	61.5	38.2	9	
Zbaszyn-Poznan	75	46.6	1.14 a. m.	1.02	72.7	45.2	...	
Poznan-Gniezno	50	31.0	R 1.22 p. m.	0.39	76.9	47.8	..	
Gniezno-Inowroclaw	57	35.4	3.16 a. m.	0.43	79.5	49.4	...	
Inowroclaw-Torun P.	34	21.1	4.50 a. m.	0.26	78.5	48.8	...	
Jablonowo P.-Jamielnik	28	17.4	R 8.34 a. m.	0.22	76.3	47.4	...	
Inowroclaw-Bydgoszcz	45	28.0	7.12 a. m.	0.35	77.1	47.9	...	
Warsaw G.-Kutno-Gydnia	466	289.6	3.30 p. m.	7.12	64.7	40.2	11	
Warsaw G.-Kutno	126	78.3	Do.	1 43	73.4	45.6	...	
Torun P.-Bydgoszcz	50	31.0	R 6.26 p. m.	0.37	81.1	50.4	...	
Warsaw G.-Kutno-Poznan-Zbaszyn	379	235.5	12.15 p. m.	5.15	72.2	44.9	2	Nord Exp.
Kutno-Poznan	178	110.6	2.05 p. m.	2.30	71.2	44.2	...	Do.
Poznan-Zbaszyn	75	46.6	4.41 p. m.	0.49	91.8	57.0	...	Do.
Lwow-Katowice-Poznan-Torun-Gdynia	1 126	699.7	6.25 a. m.	23.37	47.7	29 6	...	
(Breslau) Rawicz-Poznan (Gdynia, etc.)	101	62.8	12.43 p. m.	1.21	74.8	46.5	2	
Leszno-Koscian	27	16.8	1.09 p. m.	0.21	77.1	47.9	...	
Koscian-Poznan	41	25.5	1.31 p. m.	0.33	74.5	46.3	...	
(Gdynia) Inowroclaw-- Poznan - Katowice - Lwow	861	535.0	11.05 p. m.	15 25	55.7	34.6	23	
Warsaw G.-Lodz-Ostrow-Zduny	312	193.9	9.48 p. m.	6.16	49.9	31.0	22	Paris.
Poznan-Katowice	335	208.2	12.43 a. m.	5.37	59.4	36.9	8	Lwow.
Sroda-Jarocin	44	27.3	R 4.26 a. m.	0.29	91.0	56.5	...	
Jarocin-Ostrow	47	29.2	1.42 a. m.	0.37	76.2	47.3	...	
Warsaw G. - Zabkowice - Katowice - Zebrzydowice	318 + 79	216.2 +49.1	7.35 a. m.	6.05	64.7	40 2	5	Vienna.
Warszaw G.-Krakow	364	226.2	5.15 p. m.	5.34	65.4	40.6	6	
Do. -Koluszki	105	65.3	Do.	1.30	70.0	43.5	...	
Trzebinia-Krakow	39	24.2	7.20 a. m.	0.33	71.2	44.2	...	
Warsaw G.-Radom-Tunel-Krakow	320	198 8	6.23 p. m.	5.14	61.2	38.0	5	
Warsaw Gl.-Radom	103	64.0	Do.	1.29	69.4	43.1	...	
(Warsaw) Krakow-Lwow	341	211.9	R 6.15 a. m.	5.00	68.2	42.4	6	
Katowice-Dziedice	49	30.4	12.23 p. m.	0.40	73.5	45.7	201	Prague.
Dziedice-Zebrzydowice	30	18.6	1.12 p. m.	0.28	64.2	39.9	...	
Krakow-Krynica	227	141.0	*1.15* p. m.	*4.50*	*47.0*	*29.2*	*9*	*Summer.*
(Warsaw) Krakow-Lwow	341	211.9	R 6.15 a. m.	5.00	68.2	42.4	6	
Przemysl-Lwow	98	60.9	R 3.00 p. m.	1.13	80.6	50.1	...	
Warsaw G.-Lublin-Lwow-Sniatyn-Zalucze	730	453.6	3.16 p. m.	13.20	54.1	33.6	16	Bucharest.
(Warsaw) Lwow-Sniatyn-Zalucze	230	142.9	5.14 p. m.	3.29	66.0	41.0	3	Do.
Chodorow-Stanislawow	77	47.8	6.11 p. m.	1.04	72.2	44.7	...	
Warsaw-Bialystok-Wilno (Turmont)	423	262.8	4.30 p. m.	6.04	69.7	43.3	3	
Warsaw-Bialystok	170	105.6	4.38 p. m.	2.26	70.0	43.5	...	
Porzecze-Wilno	125	77.7	8.57 p. m.	1.37	77.3	48.0	...	
Warsaw G.-Bialystok-Stolpce	468	290.8	9.12 a. m.	7.13	65.0	40.4	...	

TABLE 260.

POLISH NON-STOP TRAIN RUNS.

RUN.	Length.		Time of departure.	Time spent.	Speed.		—
	Km.	Miles.			Km./h.	Miles/h.	
Non-stop runs.							
Locomotive-hauled trains.							
(Warsaw) Poznan-Zbasyn	75	46.6	4.41 p. m.	0.49	91.8	57.0	Nord Express.
Poznan Sroda-Jarocin	44	27.3	R 4.26 a. m.	0.29	91.1	56.6	Towards Lwow.
(Berlin) Chojnice-Tczew	97	60.3	4.16 a. m.	1.10	83.1	51.6	
(Warsaw) Torun P.-Bydgoszcz	50	31.0	R 6.26 p. m.	0.37	81.1	50.4	
(Poznan) Gniezno-Inowroclaw	57	35.4	3.16 a. m.	0.43	79.5	49.4	
Railcars.							
(Katowice) Trzebinia-Krakow	39	24.2	1.02 a. m.	0.24	97.5	60.6	
Warsaw Gl.-Lodz Fab.	140	87.0	10.25 a. m.	1.28	95.5	59.3	
(Warsaw) Koluszki-Czestochowa	125	77.7	5.11 p. m.	1.19	95.0	59.0	Towards Katowice.
(Warsaw) Czestochowa-Sosnowiec Pln.	80	49.7	6.31 p. m.	0.53	90.6	56.3	Do.
Warsaw Gl.-Koluszki	105	65.3	4.00 p. m.	1.10	90.0	55.9	Do.
Katowice-Mystowice (Krakow)	11	6.8	2.58 p. m.	0.08	82.5	51.3	Do.
Longest runs.							
Locomotive-hauled trains.							
(Warsaw) Kutno-Poznan	178	110.6	2.05 p. m.	2.30	71.2	44.2	Nord Express.
Warsaw-Bialjstok	170	105.6	4.38 p. m.	2.26	70.0	43.5	
Warsaw G.-Kutno (Gdynia)	126	78.3	3.30 p. m.	1.43	73.4	45.6	
(Warsaw) Porzecze-Wilno	125	77.7	8.57 p. m.	1.37	77.3	48.0	
Warsaw G.-Koluszki (Katowice)	105	65.3	5.15 p. m.	1.30	70.0	43.5	
Warsaw W.-Deblin (Lwow)	103	64.0	11.08 p. m.	1.31	67.9	42.2	
Railcars.							
Warsaw Gl.-Lodz Fab.	140	87.0	10.25 a. m.	1.28	95.5	59.3	
(Warsaw) Koluszki-Czestochowa	125	77.7	5.11 p. m.	1.19	95.0	59.3	
Warsaw Gl.-Koluszki (Katowice)	105	65.3	4.00 p. m.	1.10	90.0	55.9	

14 201 km. (8 824.1 miles) or 81.3 % at overall speeds of less than 60 km. (37.5 miles).

CHAPTER XLIV.

The International Sleeping-Car Company in Eastern Europe.

Since 1890, the Company has aimed at extending its Eastern services. There was a considerable unexplored field which could be further developed in the Far East, as far as China and Japan.

Thanks to the continuity of its policy, which has always characterised the development of its railway services, but unfortunately has not applied to its other activities, it was able to bring its Asiatic dream into being by running a « Transsiberian Express » from Europe to China. In spite of the War having temporarily modified its services, the Treaties which reconstituted Poland and set up the Baltic States linked these countries more closely to Western Europe. Against this, the setting up of the U. S. S. R. did away with all its former Russian services.

We will first take in sequence the Company's Polish and Baltic services, and the « de luxe », sleeping- and restaurant-car Russian services.

XLIV-1. — **The International Sleeping Car Company's Polish services.** — For a long time, the Company sought to link up pre-war St. Petersburg with Paris, where connection with the « Sud Express » would take place, a through St. Petersburg-Madrid express being hoped for in the future.

Later, it thought of linking up the

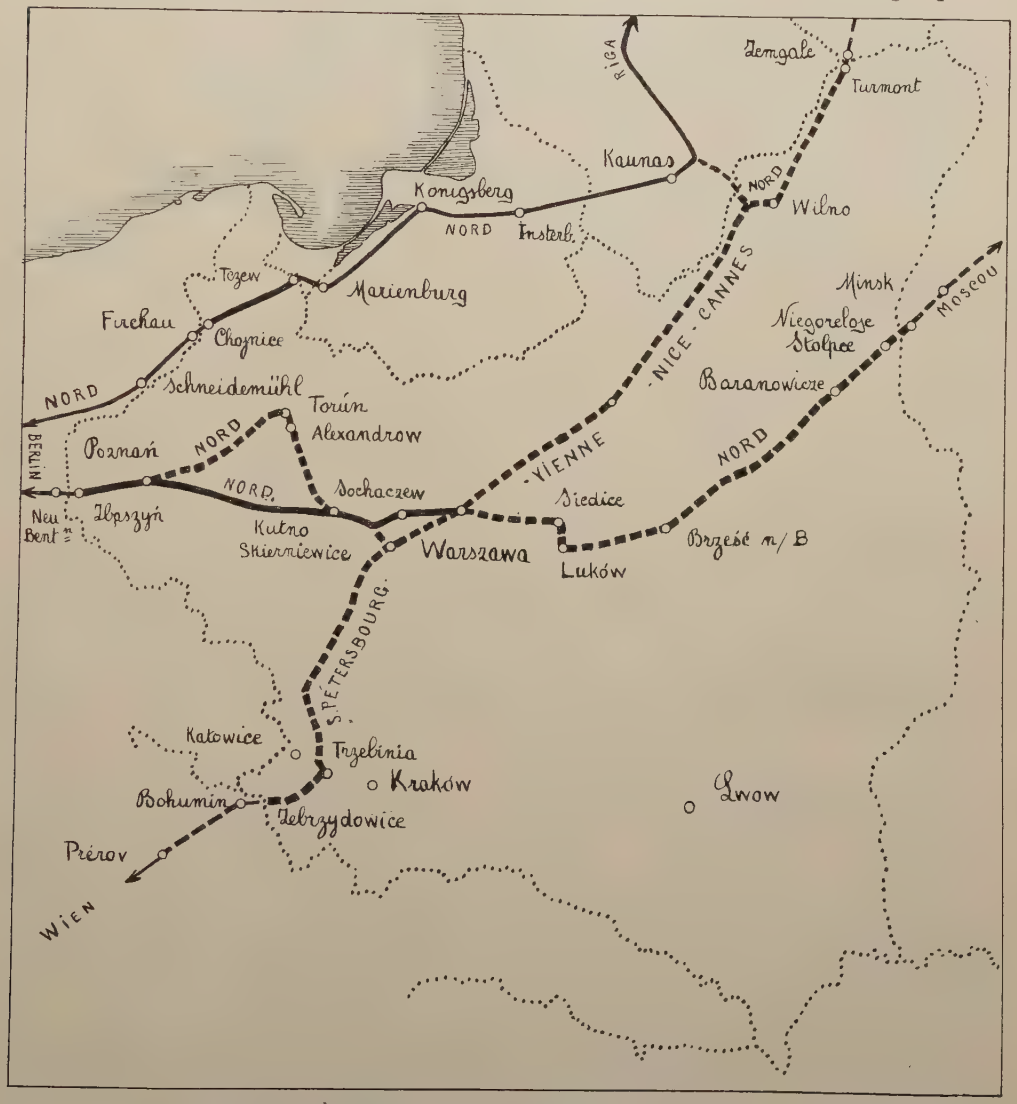


Fig. 273. — Polish sections of the International Sleeping-Car Company's « de luxe » trains.
Discontinued services are shown in bar lines.

Russian capital, like all the others, with the Riviera. Both schemes were carried into effect and two « de luxe » trains run through present-day Poland (fig. 273).

The « Nord Express », the oldest of the two, was started in 1896. Coming from Paris (London), Calais and Ostend it was split up into two portions in Berlin, one of which ran to St. Petersburg (Le-

TABLE 261.

POLISH SECTIONS OF INTERNATIONAL SLEEPING-CAR Co. TRAIN SERVICES.

(Obsolete runs are shown *in italics.*)

Origin.	Polish section.	Destination.	Distance. Km.	Distance. Miles.	Time of departure.	Time spent.	Number of stops.	Name of train.
	West to East transit.							
Paris N. Ostend Calais.	*Chojnice-Wilno* .	*St.-Petersburg.*	602(1)	374.1(1)	*7.36* p. m.	*2.43*	*2*	*Nord Express.*
Paris N. Ostend Calais.	Chojnice-Malbork .	Kaunas, Riga.	115	71.5	1.30 p. m.	1.32	1	Nord Express.
Do.	*Alexandrowo - Warsaw-Brzesc-Minsk* .	*Moscow.*	963(2)	598.4(2)	*3.33* p. m.	*21.33*	*8*	*Nord Express.*
Do.	Zbaszyn-Warsaw .	...	379	235.5	12.12 p. m.	5.23	2	Nord Express.
	ISOLATED SERVICE.							
Ostend.	Beuthen-Lwow-Sniatyn . . .	Bucharest.	666	413.8	4.54 p. m.	11.42	12	Do.
	North to South tran it.							
St.-Petersburg.	*Dukszty-Warsaw and Warsaw - Zebrzydowice*	... Bohumin, Vienna, Cannes.	(3)571+ 484(4)	(3)354,8+ 300.7(4)	*2.29* a. m.	*19.58*	*16*	*St.-Petersb.-Vienna-Nice-Cannes.*
	Internal trains.							
...	Warsaw-Poznan . .	...	304	188.9	*11.10* p. m.	7.09	6	*3rd-cl. all-sleeping-car train.* (1929).

(1) There also some 22 km. (13.7 miles) in Polish territory, from Wilno to the frontier station of Turmont.

in the total distance given) is 21 km. (13 miles), 16 km. (9.9 miles) of which are in the case of the run to Minsk, by the distance from Stolpce to Minsk.

(3) The distance from the Polish station of Zebrzydowice to Bohumin (which is included in the total distance given) is 21 km. (13 miles), 16 km. (9.9 miles) of which are in Czechoslovakia.

(4) Only line in former Poland, built to standard gauge.

ningrad) the other, to Moscow. Since the War these trains have been diverted to Riga and Warsaw respectively.

a) The Northern Portion has remained unchanged except for this alteration in its destination. It crosses Poland between Chojnice (330th km. = 205th mile from Berlin Schl.) and Malbork (Marienburg, 444th km. = 276th mile), and is routed via Kaunas (828th km. = 514th mile) (1). It used to run through what is now Polish territory, at Zawiasy 42 km. (26.1 miles) from Wilno (2) and 104 (64.6 miles) from Kaunas, continuing via Zemgale (present-day frontier) to St. Petersburg (1 632nd km. = 1 014th mile).

The distance covered in this way between Berlin and Wilno is 936 km. (581.6 km.) whereas it would be 986 km. (612.7 miles) via Warsaw and Bialystok. Riga, the present terminus, is 1 120 km. (696 miles) from Berlin Schl.

b) The Southern portion has changed its route several times. There was formerly no direct communication between Poznan and Warsaw, and beyond Zbaszyn (Bentschen), the train ran via Poznan, Torun (Thorn), and Skierniewice, to Warsaw, a journey of 459 km. (285.2 miles) in all. It then proceeded via Siedlce, Stolpce (the present frontier, 416 km. = 258.5 miles from Warsaw), on to Moscow, where it connected up with the « Transsiberian Express ».

Since the War, two important alterations have been made in this service : it now ends at Warsaw, and its route has been altered between Poznan and Warsaw, owing to the construction of the Poznan-Kutno cut-off and doing away with the roundabout Skierniewice route. This has shortened the journey by 87 km. (54.1 miles), so that Warsaw is now but 563 km. (349.8 miles) from Berlin Schl. instead of the former 643 (399.5 miles).

During the War this train, of course, had to be discontinued, and it has been rerouted along its former German route since the 15th May 1926 only. Meanwille a temporary « de luxe » train running around Southern Germany linked up Paris with Warsaw. This was the « Orient Prague-Vienna-Warsaw Express » which was introduced in 1919. In 1920, this service was removed from the Paris-Basle to the Paris-Strasbourg line, where a rake from Ostend joined up; it then ran solid to Prague and Warsaw with a Viennese rake which was detached on the way.

Like both original portions of the « North Express » the « St. Petersburg-Vienna-Nice-Cannes Express » followed a broad-gauge line from St. Petersburg to Warsaw, a distance of 1 116 km. (1 356.4 miles), 571 km. (354.8 miles) of which — from Turmont — are in present day Poland). South of Warsaw it ran, over standard-gauge track, via Trzebinia (half way between Katowice and Krakow), the distance as far as the frontier at Zbrzydowice being thus 463 km. (287.7 miles), 753 km. (467.9 miles) as far as Vienna North (3), and 1915 (1 189.9 miles) as far as Cannes.

Between the time it arrived at the first Warsaw terminus and that at which it left the second, 1 h. 16 m. elapsed in the case of the « Nord Express » (Vienna

(1) We have taken the verst as equal to 1 067 m. (0.663 mile).

(2) Formerly the frontier station of Wirballen was 741 km. (460.4 mile) from Berlin Schl., and Wilno 931 km. (578.5 miles).

(3) 10 km. (6.2 miles) in addition as far as Vienna West.

and Brzesc stations), and 1 h. 19 m. (Weschsel-Prague and Vienna stations) in the case of the « St. Petersburg-Vienna-Nice-Cannes ».

XLIV-2. — **The International Sleeping Car Company's rolling stock for the 1.52-m. (5′) gauge lines.** — Between Riga and Tallinn the *International Sleeping-Car Co.* runs both old Russian 5-foot gauge stock and standard-gauge car bodies on 5-foot gauge bogies.

This is exactly the opposite to the Brazilian *Paulista Railway*'s policy where some time ago, 1.60-m. (5′ 3″) sleeping- and restaurant-car bodies where mounted on metre-gauge bogies.

Table 262 gives the leading dimensions of the converted restaurant cars and 3rd-class standard gauge sleeping cars Nos. 3001/3, specially built for the Polish and Baltic States.

For comparative purposes we have added the dimensions of the sleeping-, restaurant- and Pullman cars used on the Spanish 1.67-m. (5′ 6″) gauge lines. Here again, though mounted on broad-gauge bogies, these carriages have bodies built to the standard loading gauge.

The 1922 third-class sleeping cars have 9 four-berth compartments, and a two-berth one.

XLIV-3. — **The International Sleeping Car Company's Russian services.** — In 1886, the Company signed its first Russian agreement, which covered sleeping- and restaurant-car services.

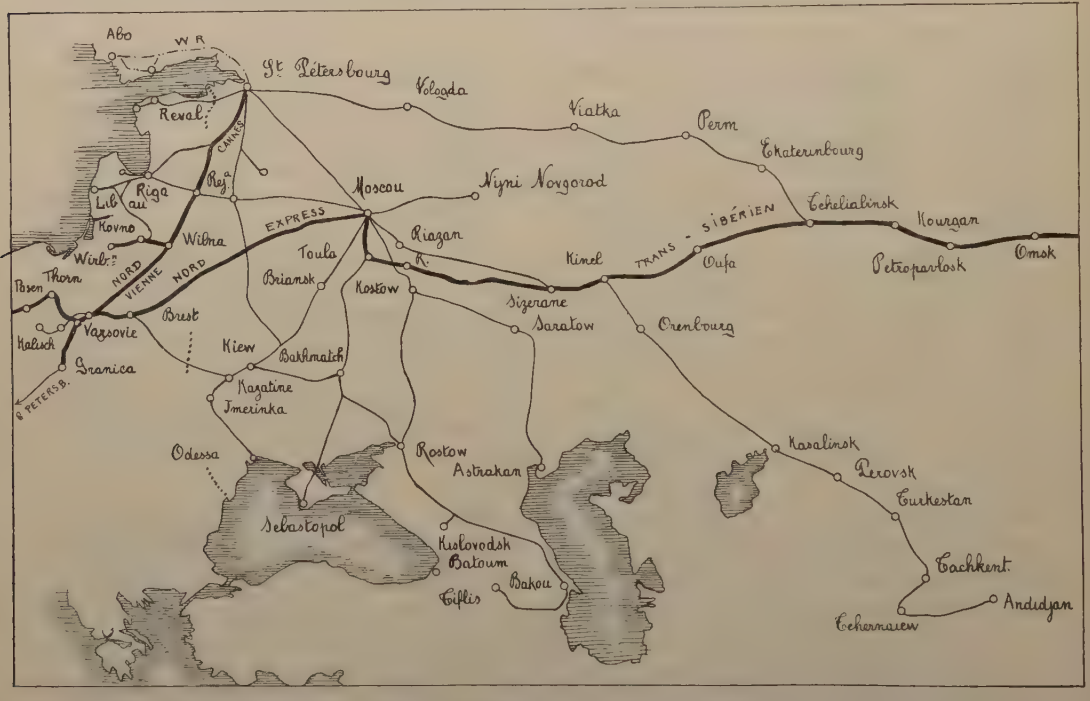


Fig. 274. — The International Sleeping-Car Company's Russian services in 1914.
Routes of « de luxe » trains are shown by heavy lines; sleeping car services by thin lines.

Table 262.

LEADING DIMENSIONS OF BROAD-GAUGE ROLLING STOCK OWNED BY THE INTERNATIONAL SLEEPING-CAR Co.

TYPE OF VEHICLE.	Sleeping car. 1st cl.	Rest^{t} car. All-metal.	Restaurant car.	Pullman car.	Sleeping car. 3rd cl.	Sleeping car. 1st. cl. Old.	
Date	1927/1935	1927	1928	1928	1922	1901	1902
Number	3361/80	3567/9	3224/9	...	3604/9	682/691	35 vehicles only one, No. 882, still extant.
Gauge . . . m.	1.67 (5′ 6″)	1.67 (5′ 6″)	1.435 (4′ 8 1/2″) converted to 1.52 (5′)	1.67 (5′ 6″)	1.52 (5′)	1.52 (5′)	1.52 (5′)
Length, overall . . . m.	21.550 (70′ 8 15/32″)	21.550 (70′ 8 1/2″)	19.740 (64′ 9″)	21.552 (70′ 8 1/2″)	23.456 (76′ 11 1/2″)	20.840 (67′ 2 5/16″)	21.180 (69′ 6″)
Do. over vestibules . . m.	20.300 (66′ 7 1/4″)	20.300 (66′ 7 1/4″)	18.500 (60′ 8 11/32″)	20.300 (66′ 7 1/4″)	22.200 (72′ 10″)	19.200 (63′)	20.000 (65′ 7 7/16″)
Do. of underframe . m.	20.300 (66′ 7 1/4″)	20.300 (66′ 7 1/4″)	18.240 (59′ 10″)	20.300 (66′ 7 1/4″)	21.940 (72′)	19.000 (62′ 4″)	19.800 (64′ 11 1/2″)
Do. of body . . . . m.	18.600 (61′ 5/16″)	18.600 (61′ 5/16″)	16.800 (55′ 1 1/2″)	18.500 (60′ 8 11/32″)	20.500 (67′ 3″)	17.500 (57′ 5″)	... ...
Outside height . . . . m.	4.005 (13′ 1 5/8″)	4.005 (13′ 1 5/8″)	4.025 (13′ 2 1/2″)	4.005 (13′ 1 5/8″)	4.005 (13′ 1 5/8″)	4.160 (13′ 7 13/16″)	4.470 (14′ 8″)
Outside width . . . . m.	2.962 (9′ 8 5/8″)	2.962 (9′ 8 5/8″)	2.750 (9′ 9/32″)	2.954 (9′ 8 5/16″)	2.834 (9′ 3 19/32″)	3.046 (10′ 5/64″)	3.120 (10′ 2 13/16″)
Bogies, wheel base . . . m.	2.500 (8′ 2 7/16″)	2.500 (8′ 2 7/16″)	2.500 (8′ 2 7/16″)	2.500 (8′ 2 7/16″)	2.500 (8′ 2 7/16″)	2.500 (8′ 2 7/16″)	2.500 (8′ 2 7/16″)
Bogies, distance between centres . . . . . m.	14.500 (47′ 7″)	14.500 (47′ 7″)	13.200 (43′ 3 23/32″)	14.500 (47′ 7″)	16.000 (52′ 6″)	13.000 (42′ 8″)	14.000 (45′ 11″)
Weight, empty . . Metr. t. (Engl. t.)	50.6 (49.8)	53.4 (52.8)	40.0 (39.4)	46.0 (45.3)	50.5 (49.7)	40.0 (39.4)	46.5 (45.8)
Seats	...	48 + kitchen.	40	24	38	...	...
Berths	12 + 4	...	...	...	...	18	17

The first vehicles, specially designed in 1880, while larger and longer than any the Company so far built, had three pairs of wheels and carried 14 passengers only.

Owing to weather conditions the vestibules were closed in for the first time. Double floors with compressed pasteboard in between, and double windows, were provided.

« DE LUXE » TRAINS. — In 1896 the Company introduced the first Russian « de luxe » train on 1.52-m. (5′) gauge lines. Thanks to the ample-size loading gauge, the dimensions of the rolling stock were more generous than those of the standard-gauge cars. Passengers always changed trains at the frontier.

TABLE 263

LEADING DIMENSIONS OF 5-FOOT GAUGE ROLLING STOCK BUILT FOR SERVICE IN RUSSIA.

Kind of vehicle	Sleep. car	Sleep. car	Restᵗ car	Lugg. van
Date	1880	1900	1900	1900
Number of wheels	6	8	8	8
Number of seats	14	18	36	...
Wheelbase . . . m.	7.50 (24′ 7 9/32″)	...	...	...
Distance between bogie centres . . . m.	...	14.000 (45′ 11 3/16″)	14.000 (45′ 11 3/16″)	14.000 (45′ 11 3/16″)
Length of body . . . m.	...	18.300 (60′ 15/32″)	18.300 (60′ 15/32″)	18.300 (60′ 15/32″)
Length over buffers . . . m.	13.74 (45′ 1″)	21.28 (69′ 9 27/32″)	21.28 (69′ 9 27/32″)	21.28 (69′ 9 27/32″)
Outside width . . . . . m.	...	3.046 (10′)	3.046 (10′)	3.046 (10′)
Tare . . . . . Metr. t. (Engl. t.)	19.2 (18.9)	41.2 (40.6)	34 to 36.7 (33.5 to 36.2)	43.3 (42.9)

The « Nord Express » ran between Paris, Ostend (with a rake from Calais), Berlin and St. Petersburg; we have mentioned the Russian part of this service when dealing with the *International Sleeping Car Co.'s* Polish services.

On the 1/13th April 1898 the Company signed with the Russian Empire a general contract renewing all previous agreements and introducing a new « St. Petersburg-Vienna-Nice Express » — which we have already mentioned. It was also authorised to run a « Transsiberian train », giving a 20-days service between London and Shanghai, and Japan. This latter is the only train we still have to deal with.

It was introduced in 1903, as far as the railhead, which reached the Pacific in 1906, and was to be an extension of the « Nord Express » from Moscow to Irkutsk and Vladivostok. This train consisted of two 1st-class and two 2nd-class sleeping cars, a restaurant-saloon, and a van, specially designed to withstand the cold and to take the length of the journey into account. This rolling stock is noteworthy because it marked considerable progress as regards dimensions and comfort, on all that built

previously. The interior arrangement of the sleeping cars was derived from that of the carriages which had just been built for Egypt, but the number of berths was increased to 18 first, or 26 second class. The bogie vans had compartments for the staff, a bathroom, a hair-dressing saloon, a pantry, a luggage compartment, beside a boiler, a steam turbine and a dynamo for the electric lighting of the entire train.

The « Transsiberian » made it possible to reach Tokio in 14 days, Pekin in 12, and Vladivostok in 9. It was duplicated beyond Irkutsk by a train, running twice weekly, and comprising a restaurant car and ordinary sleeping cars without intermediate dressing rooms, which the *Int. Sleeping-Car Co.* also operated according to the same timetable.

Both trains connected at Irkutsk, with a sleeping-car service from St. Petersburg, via Tcheliabinsk. They ran until the 1st January 1919.

Isolated services. — As will be noticed, the number of Russian services increased rapidly and in 1914 totalled 38 (27 sleeping-car and 11 restaurant-car services), besides the Siberian services, and 7 services (4 sleeping-car and 3 restaurant-car) outside the present Soviet Republic. A fleet of 300 cars was divided up among the five divisions of St. Petersburg, Moscow, Kiev, Irkutsk, and Vladivostok; the Company owned 3 repair shops, at St. Petersburg, Moscow and Vladivostok.

These isolated services were also maintained during the whole of the War.

Services of the U. S. S. R. — On the 1st January 1919, the Soviet Government seized all but a small part of the Company's rolling stock. A few of the 1.52-m. (5′) gauge cars are still running in the Baltic States and in Finland; a few of the remainder have been converted from the 5′ to the 4′ 8 1/2″ gauge and used elsewhere.

U. R. S. S. « de luxe », sleeping-car and restaurant-car train services. — The « Transsiberian » is now operated by the *Soviet Railways* and, as in former times, is duplicated by an ordinary express train. This latter, known as the « Blue Express » runs between Stolpce (on the Polish frontier), Moscow, and Manchouli. It includes « hard » and « soft » stock and a mixed 1st- and 2nd-class sleeping car.

The « de luxe » train only includes 1st and 2nd-class sleeping cars and a restaurant car. It is possible, by either of these trains, to travel from London to Manchouli in 9 days.

The Soviet Railways now operate some 26 sleeping-car services :

Leningrad (Wars.)-Warsaw (Pet).
Do. -Riga.
Do. (Balt.)-Reval-Gapsal.
Do. -Moscow (Koursk) Kislovodsk.
Do. -Moscow (Koursk)-Sebastopol (2 services).
Do. (Nicolas)-Moscow (Nicolas) 2 services).
Do. -Omsk-Irkutsk-Vladivostok.
Do. (Finland)-Helsingfors (2 serv.) (1).
Do. -Moscow-Tsaritzine.
Do. (Tzark. Selo)-Kieff.
Do. -Staraia Russa.
Moscow (Kazan)-Tachkent-Andijan.
Do. (V. Ryb)-Rjeff II Riga.
Do. (Kursk)-Nijni Novgorod.
Do. -Melitopol.
Do. (Kazan)-Kislovodsk.
Do. (Alexandre)-Warsaw (Kovel) (2 services).
Do. (K. V.)-Kieff.
Do. (Poveletsk-Saratoff.
Reval-Riga.
Saratoff-Astrakan.
Kharkoff-Lugansk.

(1) These services are worked by means of sleeping cars belonging to the *Finnish State Railways.*

APPENDIX.

WAGONS RUNNING ON STANDARD AND RUSSIAN GAUGES.

When dealing with the international services between the States along the Baltic coast and Russia, we mentioned the fact that some rolling stock could be used on both the standard and Russian broad-gauge lines. As we have not so far come across any description of the systems used, it serves a useful purpose to publish some information on the subject.

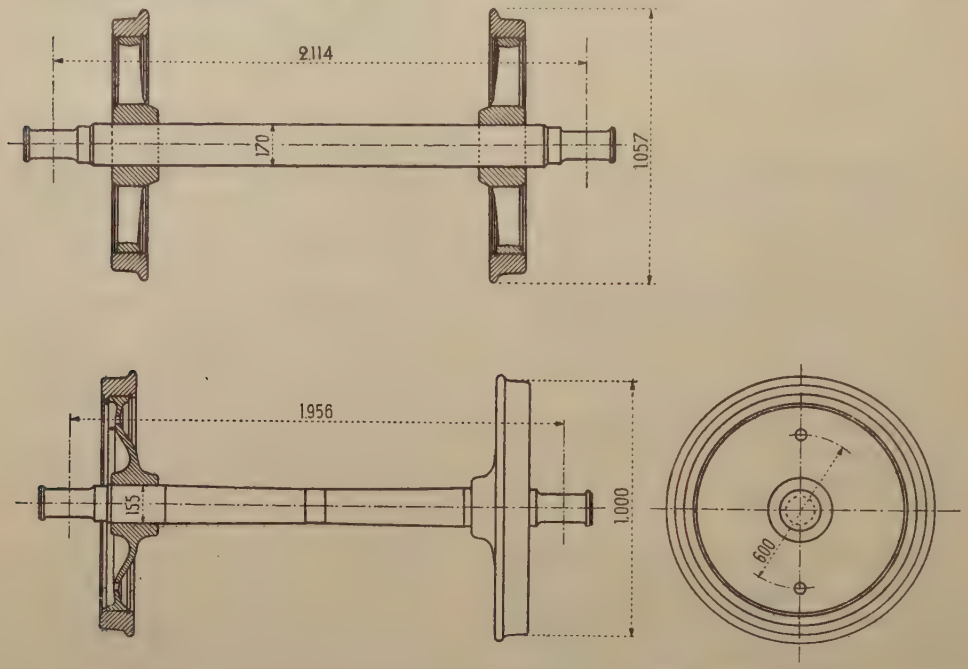


Fig. 275. — *a*) Standard-gauge axle fitted to broad-gauge vehicle; *b*) Broad-gauge axle fitted to standard-gauge vehicle.

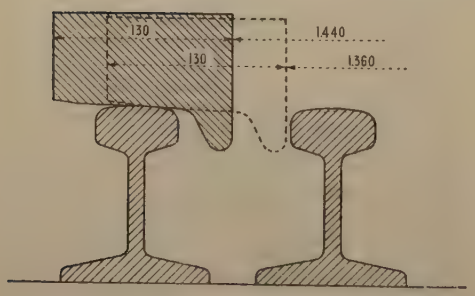


Fig. 276. — Tyres on broad- and standard-gauge wheels.
On a narrowed section of broad gauge line, fitted with check rails.

The regulations relating thereto are now published in No. 79 of the *U. I. C. (International Railway Union)*.

In the case of Polish wagons used in Polono-Soviet traffic electric cranes lift the bodies, at the exchange stations, off the standard-gauge wheels and boxes and lower them on to 1.52-m. (5′) gauge wheels and boxes, or vice versa. Figures 275 and 276 clearly show how this is done.

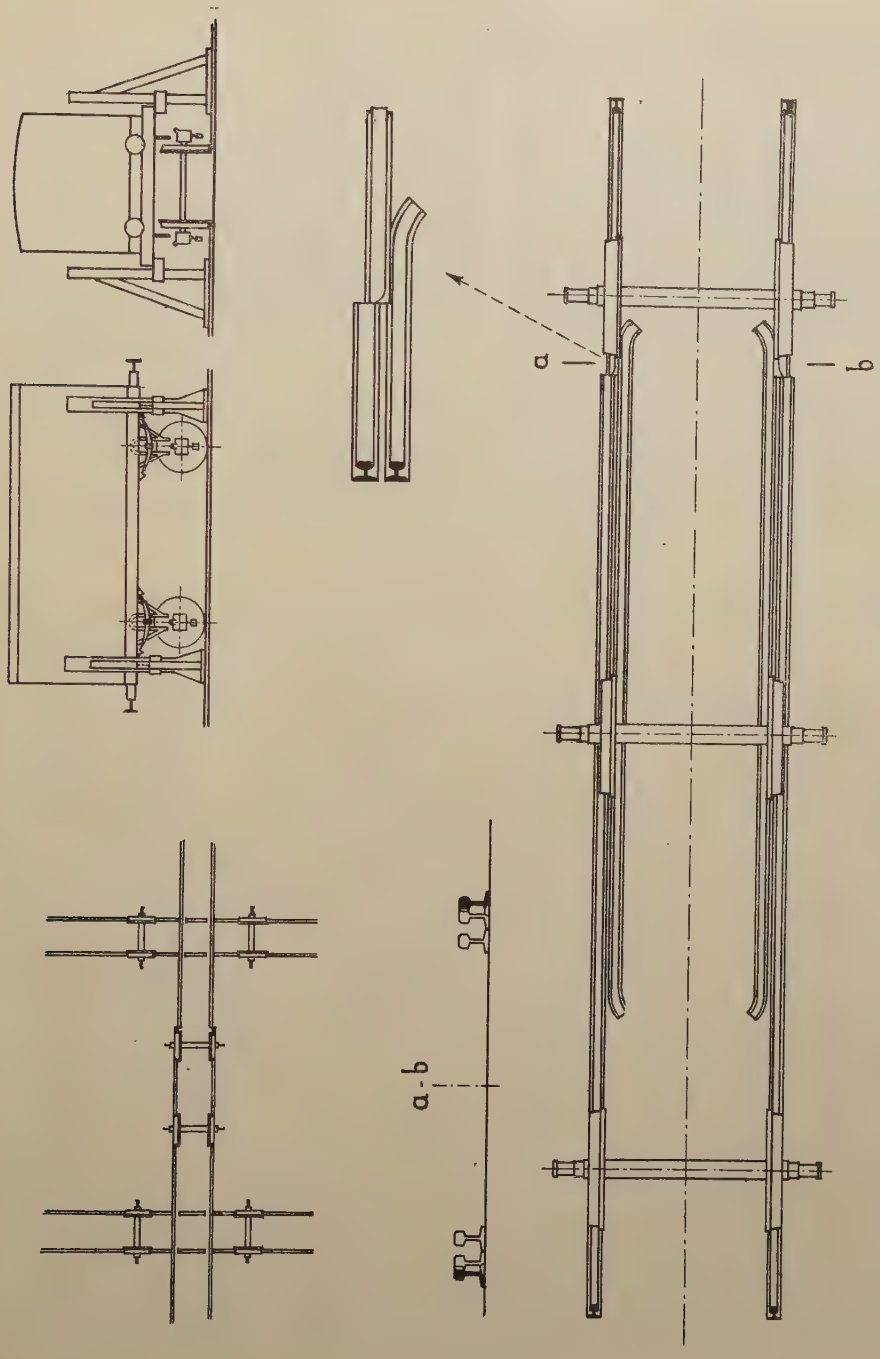


Fig. 277. — *Latvian Railways.*

Substitution of standard-gauge axles for broad-gauge axles, and broad gauge track section followed by a narrowed-in track section with check rail, and finally a section of standard-gauge track.

Owing to the difference in the gauges being slight, the method of changing the wheels, as shown in figure 277 *(Latvian Railways)* makes use of the 0.019 m. (3/4″) play of the broad-gauge wheels, as well as of the width of the tyres.

The play of the broad-gauge wheel flanges is 0.010 m. (25/64″) more than that of the standard gauge which is 0.009 (23/64″). Consequently in the transition section, the broad-gauge line has to be narrowed to suit 1.515 m. (4′ 11 5/8″). Check rails help to keep the wheels in place in order to prevent standard-gauge wheels from falling between the broad-gauge rails. Finally, the track is gradually narrowed in from 1.515 m. (4′ 11 5/8″) to 1.435 m. (4′ 8 1/2″) gauge.

The conversion is carried out as follows : the vehicle is brought onto the transition track and the axle guard stays, taken off. A lifting bar is placed across each end of the underframe and the whole is lifted or lowered by electric jacks. The wheel sets fitted so far are removed and those of the other gauge run into position and the vehicle lowered onto them. (The axle boxes are counterbalanced to prevent them from turning over). The brake shoes are then fitted with adjusting pieces. The whole operation takes 5 minutes.

XV. — FINLAND.

CHAPTER XLV.

The Finnish railway system, which includes 5 315 km. (3 302.6 miles) of lines built to the Russian 1.52-m. (5′) gauge [1] has not undergone any great modifications since the country is independent, as its railway administration was already autonomous before the War.

The great longitudinal line from Helsinki to Tornio is 885 km. (549.3 miles) long. A railway bridge crosses the frontier river and connects Tornio with the Swedish town of Haparanda (see hereafter under « Sweden »).

TABLE 264.

NOTEWORTHY RUNS OF FINNISH TRAINS.

(Non-stop runs are shown in **heavy** type.)

RUN.	Distance.		Time of departure.	Time spent.	Speed.		Number of stops.
	Km.	Miles.			Km./h.	Miles/h.	
Helsinki-Rajajoki (Leningrad)	409	254.2	12.20 p. m.	7.50	52.2	32.4	20
Helsinki-Viipuri	313	194.5	Do.	5.10	60.6	37.7	4
Helsinki-Riihimäki	71	44.1	**Do.**	1.07	60 6	37.7	...
			R 5.42 p. m.	1.05	65.5	40.7	...
Riihimäki-Lahti	59	36 7	1.39 p. m.	0.54	65.5	40.7	...
Lahti-Kouvola	62	38.5	2 35 p. m.	0.53	70.2	43.6	...
Kouvola-Simola	81	50.3	3.38 p. m.	1.13	66.6	41.4	...
Simola-Viipuri	40	24.9	4.52 p. m.	0.38	63.2	39.3	...
Helsinki-Turku (Abo)	200	124.3	R 11.15 a. m.	3.27	57 9	36 0	...
Helsinki-Karjaa. Karis	87	54.1	3.00 p. m.	1.24	62 2	38.6	..
Salo-Turku (Abo)	56	34.8	5.40 p. m.	0.55	61.1	38.0	...
Helsinki-Seinäjoki	419	260 4	8.50 p. m.	10.10	41.9	260.4	14
Helsinki-Tampere	187	116.2	2.20 p. m.	2.46	68.9	42.8	3
Helsinki-Hämeenlinna	108	67.1	**Do.**	1.32	70.4	43.7	...
Helsinki-Riihimäki	71	44.1	R 8.30 p. m.	1.00	71.0	44.1	...
Riihimäki-Hämeenlinna	37	23.0	R 7.58 p. m.	0.31	71.6	44.5	...
Hämeenlinna-Toijala	39	24.2	R 7.22 p. m.	0.34	68.9	42.8	...
Toijala-Lempäälä	19	11.8	4.30 p. m.	0.15	76.0	47.2	...
Lempäälä-Tampere	21	13.0	4.46 p. m.	0,20	63.0	39.1	...
Tampere-Orivesi	42	26.1	1.08 a. m.	0.59	44 6	27.7	...
Tornio-Kauliranta	75	46.6	11.00 a. m.	2.20	32.1	19.9	12 + 11 cond.
Tornio-Haparanda (Stockholm)	4	2.5	10.55 a. m.	0.10	24.0	14.9	...

(1) The first Finnish railway was that from Helsinki to Tavastehusj (108 km. = 67.1 miles) opened in 1862.

On each bank of the river, a railway line runs north. The Finnish line is 75 km. (46.6 miles) long and ends at Kauliranta; the Swedish line, on the other side, ends at Overtornea and is 73 km. (45.4 miles) long.

The other two longitudinal lines are shorter. The central line joins the port of Kotka with Montiomäki and is 518 km. (321.9 miles) long; the eastern one, from the harbour of Viipuri to Oulu, is 746 km. (463.6 miles) long.

TABLE 265.

FINNISH NON-STOP RUNS.

RUN.	Distance.		Time of departure.	Time spent.	Speed.	
	Km.	Miles.			Km./h.	Miles/h.
Fastest runs.						
(Helsinki) Toijala-Lempäälä .	19	11.8	4.30 p. m.	0.15	76.0	47.2
(Helsinki) Riihimäki-Hämeenlinna	37	23.0	R 7.58 p. m.	0 31	71.6	44.5
Helsinki-Riihimäki	71	44.1	R 8.30 p. m.	1.00	71.0	44.1
Longest runs.						
Helsinki-Turku (Abo) . . .	200	124.3	R 11.15 a. m.	3.27	57.9	36 0
Helsinki-Hämeenlinna . . .	108	67.1	2.20 p. m.	1.32	70.4	43.7
Helsinki-Karjaa (Karis) . .	87	54.1	3.00 p. m.	1.24	62.2	38.7
(Helsinki) Lahti-Kouvola . .	81	50.3	3.38 p. m.	1.13	66.6	41.4

The Haapamäki-Elisenvaara transverse line is 345 km. (214.4 miles) long, but the most important line is obviously that from Helsinki to the frontier station of Rajajoki (409 km. = 254.2 miles), as it gives direct communication with Leningrad.

A characteristic of the system is the great number of « halts » which are only 1 or 2 km. (0.6 to 1.2 miles) apart, and where certain trains stop conditionally.

It is an agreeable surprise, after the slowness of the Baltic States train services to find here speeds exceeding 70 km. (43.5 miles) an hour, and non-stop runs more than 100 km. (62 miles) long, the more noteworthy of which are given in table 265.

Out of the whole system of 5 315 km. (3 302.6 miles) :

189 km. (117.4 miles), i.e. 3.6 % are run over at overall speeds of more than 70 km. (44.0 miles) an hour;

360 km. (223.7 miles), i.e. 6.8 % at 60 to 69.9 km. (37.5 to 43.9 miles) an hour;

4 766 km. (2 961.5 miles), i.e. 89.6 % at speeds under 60 km. (37.4 miles) an hour.

SLEEPING-CAR AND RESTAURANT-CAR SERVICES. — There have never been any « de luxe » trains in Finland.

Although the three Finnish restaurant-car services (Helsinki to Turku-Abo, Viipuri and Tampere) are worked by the *International Sleeping-Car Co.* with its own stock, the sleeping cars belong to, and are worked by, the Finnish State Railways (fig. 279 and 280).

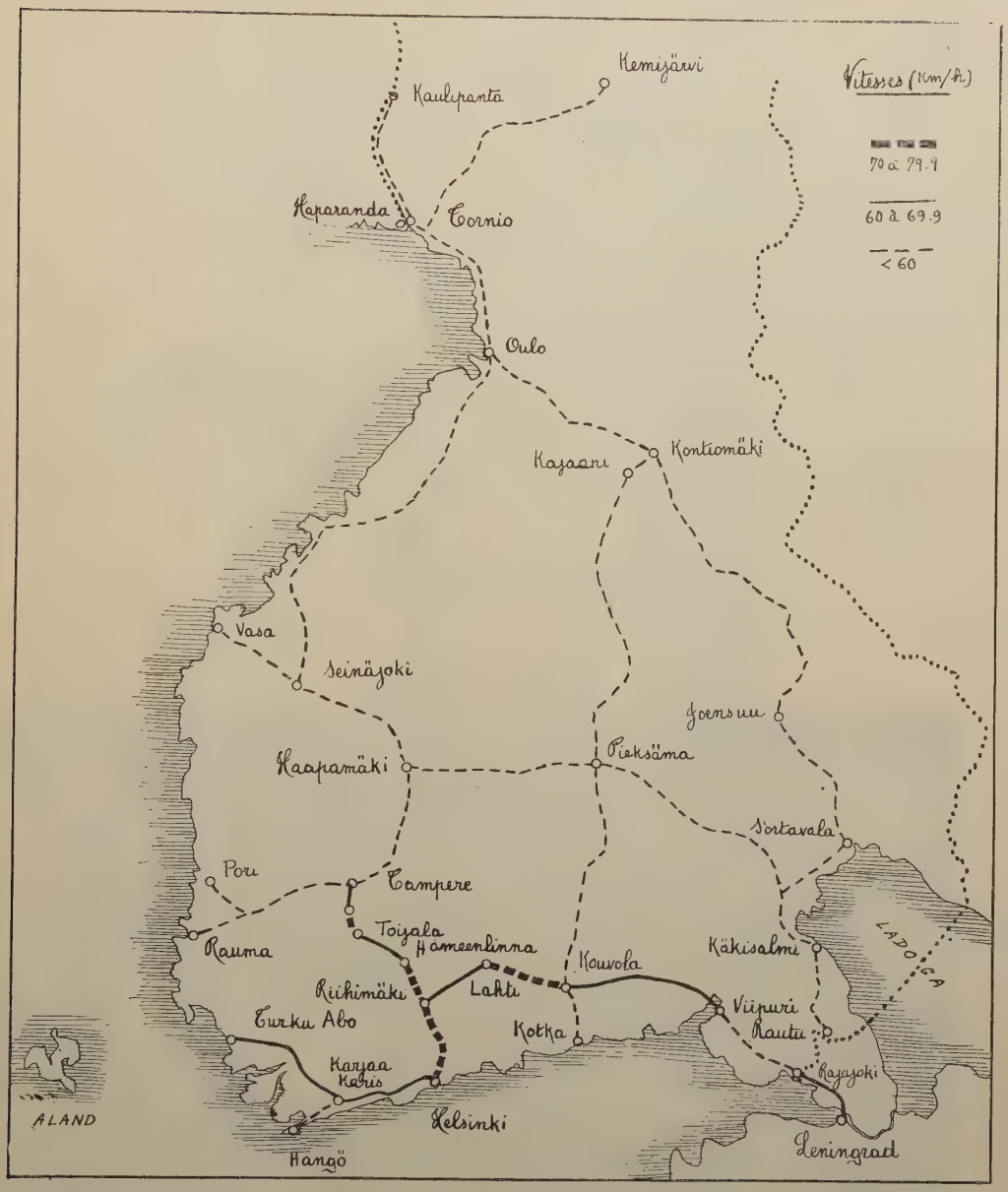


Fig. 278. — Cartogram of the maximum overall speeds of Finnish trains (1935/36 Winter).

Legend
- 43.5 to 49.9 m. p. h.
- 37.5 to 43.4 m. p. h.
- below 37.5 m. p. h.

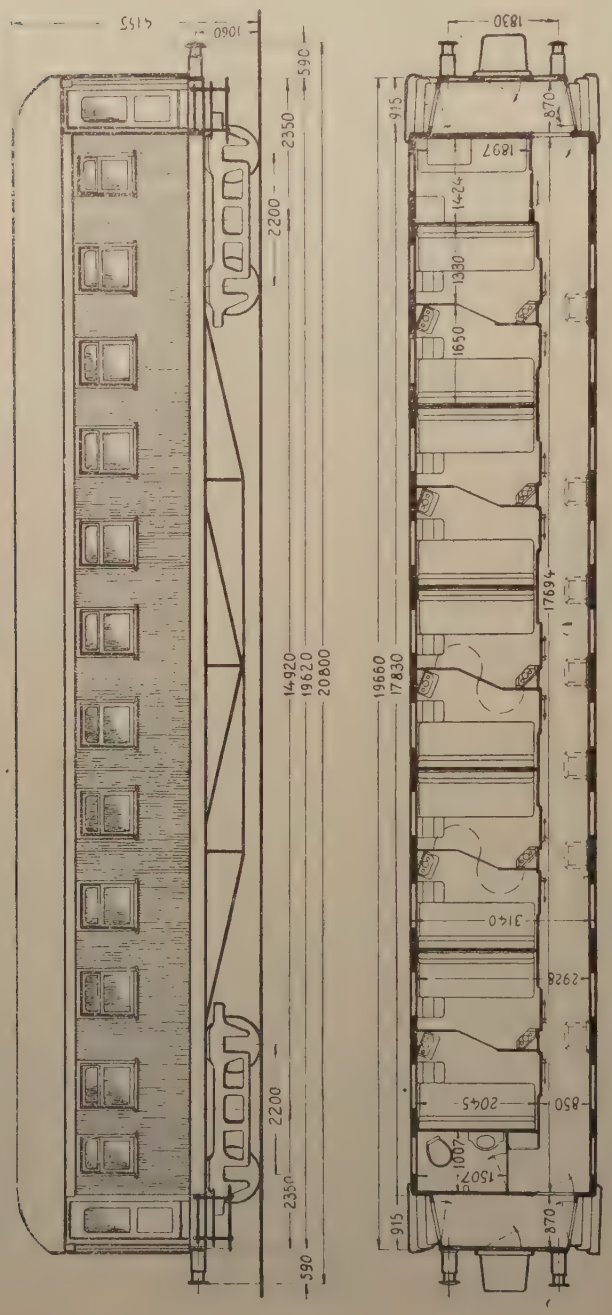


Fig. 279. — « Voiture-lits » of the *Finnish State Railways.*

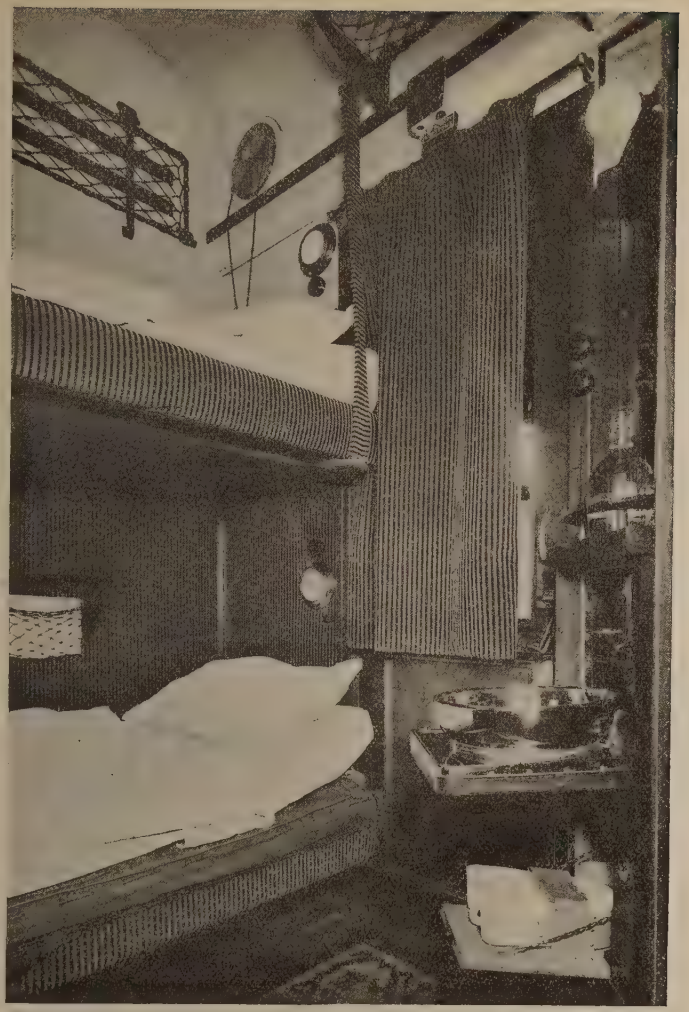


Fig. 280. — 2nd-class compartment of sleeping car, *Finnish State Railways.*

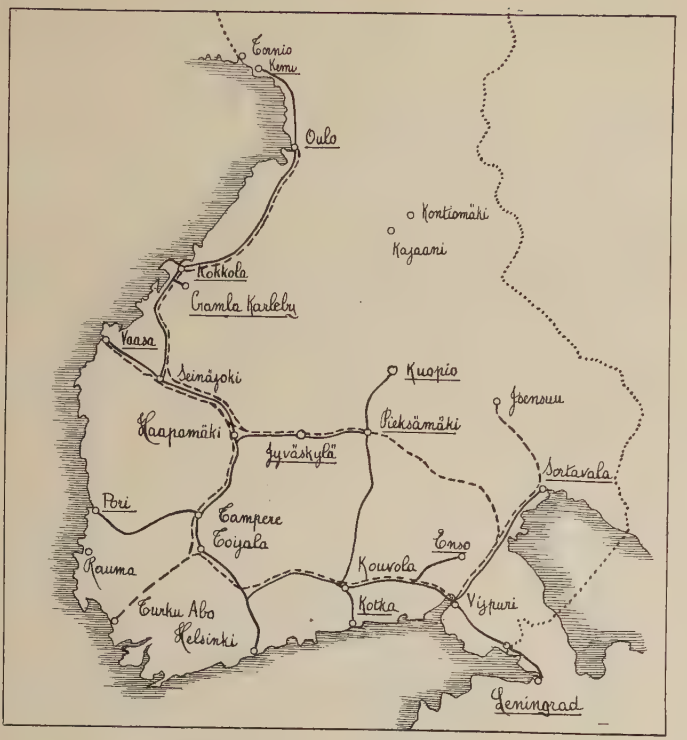


Fig. 281. — Lines served by sleeping cars of the *Finnish State Railways.*

Full lines = Services starting from Helsinki.
Bar lines = Interprovincial services.

Names of towns where services starting from Helsinki end are underlined.

There are 15 such services (fig. 281), 5 of which start from Helsinki, while 5 are interprovincial services.

There are three classes of carriages with identical leading dimensions :

Length, over buffers	20.800 m.	(68′ 3″)
Do. of underframe	19.620 m.	(64′ 4 1/2″)
Do. of body	17.830 m.	(58′ 6″)
Width, overall	3.140 m.	(10′ 3 5/8″)
Do. inside	2.895 m.	(9′ 6″)
Height, outside	4.155 m.	(13′ 7 5/8″)
Bogies, wheelbase	2.200 m.	(7′ 2 5/8″)
Do. dist. betw. centres	14.920 m.	(48′ 11 7/16″)
Number of 2nd-cl. passengers	20	
Weight, empty	37.59 t.	(36.99 Engl. tons)
Do. per passenger carried	1 880 kgr.	(4 140 lb.)

These carriages are notable because the policy followed in Northern Europe is different from that followed elsewhere, all such services (save in Germany) being maintained by the *International Sleeping-Car Co.*

(To be continued.)

[621. 133. 7]

Reducing the frequency of locomotive boiler washing-out operations,

by Hans RICHTER, Chief Engineer, Hamburg.

SUMMARY.

Frequent boiler washing-out is most uneconomical. It is almost impracticable now that the washing-out interval is becoming so short trough the much more intensive use made of the locomotives. The very desirable lengthening of the washing-out period is only possible if the boiler is blown down regularly in service. If we refer to American operating results, we see that regular blowing down produces large savings. For example, on the Illinois Central Railroad, the annual savings amounted to 232 631 dollars, although the stock of locomotives is very small when compared with that of the Reichsbahn. The regular blowing down of sludge requires a special device which can be relied upon, and is well designed. A good blow-down valve for locomotive service should meet the following requirements :

1. To be opened and shut easily in a fraction of a second, and be operated from the cab by compressed air, or steam, or by rodding.

2. The material used for the valve and seat should be rustless, with a minimum Brinell number of 600 to 800, great toughness, and high wear-resisting properties, such as are found in RV3 steel.

3. A force equal to at least 10 times the boiler pressure acting on the cone should be required to close it.

4. To be immune from failure for such reasons as part of a rivet head wedging itself between the valve cone and its seat.

5. To be fitted with a special device to brake the mud jet and deaden the loud noise whilst blowing down.

* * *

Year by year, owing to ever increasing train speeds, the services worked by steam locomotives have become increasingly difficult. The result is that the locomotive boiler has to do more work and this ultimately means a greater hourly rate of evaporation, hence the production of more mud and scale. The latter is of capital importance, as under ordinary conditions the locomotive boiler is already very sensitive to mud and scale, so that if the deposits increase, especially with a greater demand on the heating surface, the difficulty in working the service will grow considerably.

Even under present-day conditions, the locomotives have to be taken out of service every week or fortnight for washing out, a state of things which sooner or later it would not be possible to tolerate. Now, if the power developed is increased 30 %, boilers would have to be washed out every five or six days if the same relations are to be maintained. The periods between washing-out would then become so short that it would be almost impossible to work the service. The *Deutsche Reichsbahn*, with its large stock of engines, would have to proceed to over a million of boiler-washing operations every year. If we consider the direct costs thereof alone, the sum these represent is so large as to make it highly desirable to lengthen the washing-out intervals and to better protect the boilers.

The damage caused by the insulating effect of mud and scale, in spite of fre-

quent washing-out, is well known; it is chiefly of a technical nature, such as loose stays, leaky tubes, premature burning of tube ends and stay heads, and erosion of tube plates on the fire side, whereas on the water side, there is pitting of the metal, and modern investigation has shown that this is due not to insulation, but to chemical reactions and electrolysis set up by the small bubbles of carbonic acid and oxygen with which the mud is saturated.

As is known, the feed water used by locomotives can only be treated exceptionally in fixed plants, but even if treated in this way at great cost, there is no guarantee that an ideal water will be obtained. When water is treated chemically outside the boiler, the major part of scale-forming matter is, it is true, removed in the form of sludge, before the water gets into the boiler, but the water is enriched at the same time by some salts resulting from the chemical treatment. As these salts (sulphates and carbonates of soda) are dissolved in the feed water they cannot be filtered out, but are fed into the boiler where they become more and more concentrated in time. Furthermore, the water is never fully softened, even in fixed plants, but always remains at a certain degree of hardness which also deposits mud in the boiler. The soluble salts, left in chemically treated water, and carried into the boiler, increase the inherent tendency of locomotive boilers to priming. The steam carries over the mud, foam, and caustic soda solution into the cylinders and valves which soon causes grooving and other damage to these reciprocating parts. Foam and intense priming alone can make it impossible in a short time to keep the engines at work, in spite of the water being treated. The caustic soda solution used for washing out is also very harmful and dangerous in another way. It concentrates in the riveted joints and other fine grooves as well as under the mud and then causes the much dreaded caustic embrittlement of the boiler plates.

In locomotive working it must, therefore, always be remembered that the feed water, whether natural, treated in fixed plants, or treated in the boiler by adding softening material directly, always throws down harmful matter inside the boiler. The addition of suitable softening materials or any other chemical treatment of the water generally results in no adhesive matter (scale) being formed but a muddy deposit.

A particularly large amount of such matter is evidently thrown down when softening compounds are used, as to the natural formation of mud must be added that due to the chemical treatment. With high rates of evaporation, the quantity of mud thrown down rapidly becomes very important. If such mud, the salts introduced into the boiler by the chemical treatment and the soda solutions are not drained off in time, they give rise by themselves to difficulties quite as serious as those due to scale. This explains why unfavourable results have often been obtained with otherwise efficacious anti-scale-forming compounds.

Good locomotive service and full use of the action of the chemicals are only possible if the matter unavoidably thrown down in the boiler from the feed water (mud, salts, caustic solutions) *is removed from the boiler during service.*

If this be done, the boilers need not be washed out so often, a valuable feature for the reasons given above. Washing-out is not only costly, but is not completely effective as the impurities can damage

the boiler during the washing-out intervals. In addition washing out also harms the boiler owing to the sudden temperature variations it causes, such variations, in spite of all precautions taken, deforming the boiler as a whole.

A recently published report on the operating results of the Illinois Central Railroad, Chicago, shows the great savings and advantages to be obtained by removing the sludge, salts, etc., whilst running, and the extent to which, as a result, the washing-out interval can be extended.

Von Bergen, member of the Company's committee on water treatment, reported that the number of washing-out operations fell from 87 409 in 1930 to 15 889 in 1933, i.e. to one sixth, thanks to systematically blowing down the mud. The saving thereby effected, according to his calculation, was 732 631 dollars a year, for a much smaller stock of locomotives than that of the Reichsbahn. Besides these savings, another benefit was obtained : the boiler water was in first-rate order so that there was no interference with the transmission of heat nor was there any foaming.

It should be noted that these results are not those of a simple demonstration test, but of three years' regular working. Moreover these good results were obtained in spite of using at the start an improvised blow-down device that would not be suitable for regular blowing down.

It is well known that such devices as drain cocks, etc., now fitted on locomotives, are far from satisfactory : as they already soon cease to be tight when used to drain the boiler when not under pressure, they would be all the more unsuitable for frequent blowing down under full boiler pressure.

For this problem consisting in removing from the boiler the salts, sludge, etc. while running to be solved in a satisfactory way, a device so designed that it will actually do the work required from it has to be used.

Such a valve is very difficult to design owing to the very unfavourable conditions under which it always works. The discharge is not pure water, air or steam as in the case of ordinary valves, but an abrasive sludge, often mixed with hard scale and other hard foreign matter. It is well known how soon a steam or water valve breaks if a grain of sand gets into the joints. Now, with a mud blow-down valve, this is happening all the time as the sludge is full of fine and coarse grains which get into the joints, and bits of iron, such as pieces of welding rod, wires out of metal brushes, also bits of rag and other materials left in the boiler when cleaning it, are often found between the obturating surfaces of the valve. A well designed blow-down valve must be tight in spite of this. It will be appreciated, therefore, that such a valve and its obturating surfaces must be designed quite differently from any other type of valve, and different materials used.

Parts of ordinary valve cannot in any case be used to make up a blow-down valve, but a special type must be designed after taking all these special requirements into consideration.

First of all, the demands on such a valve in actual service must all be taken into account, and only then can a suitable design of blow-down valve be selected.

We will endeavour to show below the fundamental requirements a blow-down valve must meet :

1. *Fundamental question : How is the sludge to be removed?*

Many years' practical results with stationary boilers and exhaustive scientific

investigations (1) show that, owing to its higher specific weight, the dirt falls down almost as soon as formed, in the form of a semi-liquid flocculent mass, to the lowest parts of the stationary boiler and in the water legs in a locomotive boiler. Shortly after, through the vibration of the locomotive, it agglomerates and settles down, and then hardens through chemical action into a viscous and adhesive mass.

The conclusion to this is that the dirt must be removed immediately it forms, whilst it is still fluid enough to follow the water flow.

First principle :

The blow-down valve must be so arranged that, as in the case of stationary boilers, the boiler can be blown down every 30 to 60 minutes. In this case, the valve need only remain open 2 to 3 seconds, as it is found that even this short time is long enough to get rid of the sludge and other harmful matter accumulated between blow-downs (1). Thanks to this rapid rate of evacuation, there is no loss of water nor drop in pressure; each time all that is discharged is a liquid mud, i.e. nocuous matter which ought to be removed from the boiler in any case.

2. *How should the blow-down valve be operated?*

As we have seen in (1), the sludge should be blown down every 30 to 60 minutes, for only 2 to 3 seconds; the valve must be so designed that it can be opened and closed in a fraction of a second. Screw-operated valves are therefore unsuitable as they take too long to open and close. Such valves are not only hard to work, but would give rise to a big loss of water and an appreciable drop in pressure.

Second principle.

As the boiler has to be blown down frequently, it must be possible to open the valve fully and close it in a fraction of a second by means of levers. It must also be possible (by a system of rod levers or by steam or compressed-air control) to operate the valve from the engine cab while running so that engines running long distances without stops can be blown down.

3. *How should the obturating surfaces of the blown down valve be made?*

As regards the type and arrangement of the obturating surfaces, it must be remembered that they come in contact with the sludge each time the boiler is blown down. Sliding surfaces are undoubtedly unsuitable as the grit in the sludge would get between the surfaces and would jam and groove them. For the same reason, valves in which there is any sliding movement between the obturating faces are not satisfactory.

Third principle :

For obturation purposes in the case of sludge, valves which close without any sliding motion, such as cone-seated valves which cannot turn on their seats, are the only ones that can be used (see figure). Conical (oblique) surfaces are better than flat.

(1) *Brennstoff- und Warmewirtschaft*, 1935, numbers 1 and 2.

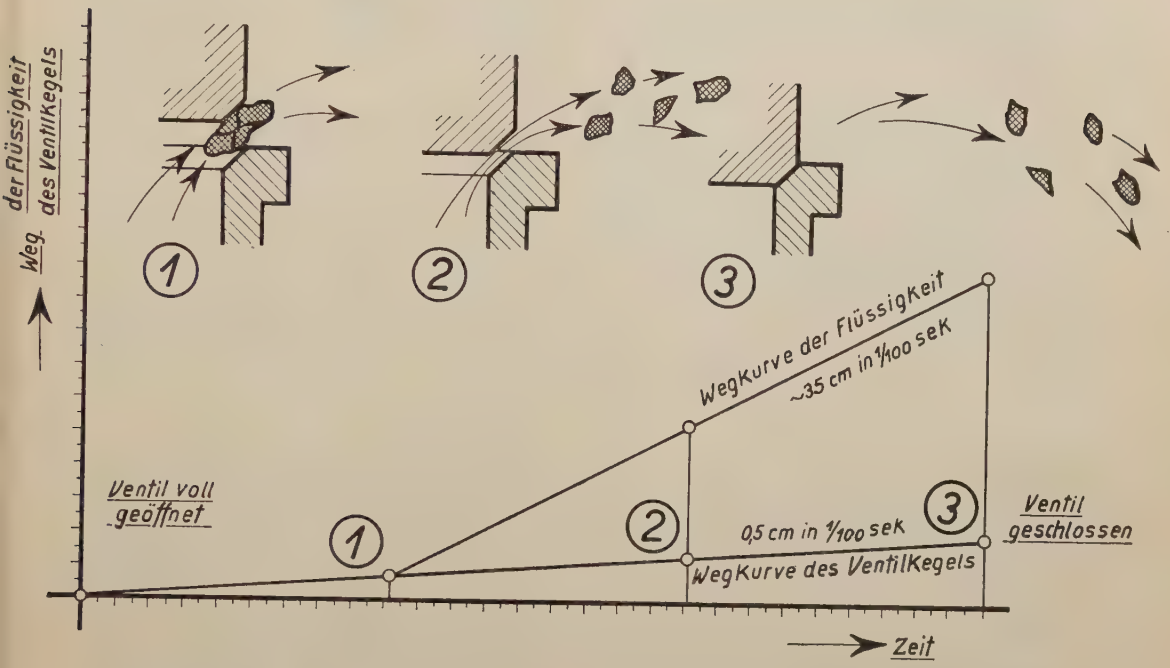


Diagram of the processus when closing the valve whilst blowing down under full boiler pressure. This diagram shows that the speed of discharge of the sludge is some 70 times that with which the valve closes. The result is that any wedged-in pieces of scale are flushed away by the rush of liquid, as they are crushed between the valve and its seat.

Wegkurve der Flussigkeit = Curve representing the path taken by the liquid (about 35 cm. (25.7 inches) per 1/100 of a second. — Wegkurve des Ventilkegels = Curve showing the travel of the valve cone. — Zeit = Time. — Ventil voll geöffnet = Valve fully open. — Ventil geschlossen = Valve shut.

4. What materials should be used for the obturating surfaces?

The pieces of scale in the sludge are often very hard, especially when they contain silicates. Then too it must be borne in mind that other foreign bodies, such as pieces of welding rod, shot of weld metal, etc., find their way between these surfaces, the material of which must therefore be vary hard, i.e. harder than the scale. Owing to the speed of extraction, the sludge has an abrasive and polishing action on the materials of the obturating surfaces which must consequently possess real wear-resisting properties. In addition, the sludge contains matter such as dissolved soda, carbonic acid and oxygen which attack the metal, and in addition electrolysis takes place.

A suitable rustless steel sufficiently hard is difficult to develop as the alloys in rustless steel are opposed to great hardness. This problem must nonetheless be solved if a reliable blow-down device is to be developed; in the end the kind of material is the essential problem, everything else depending more or less upon

it. The new KV3 steel (*) appears to meet the requirements as has been proved in practice.

Fourth principle :

The material of the obturating surfaces of the blow-down valves must be very hard (600 to 800 Brinell number at least) and, in addition, rustless and not attacked by the soda solution, besides having great resistance to wear and to electrolytic action.

5. *How should the blow-down valve shut off?*

As pieces of scale and even bits of metal can find their way between the seat and the coned valve, the cone should be held against the seat with considerable force, as if insufficient force be used the hardness of the faces of the joints is useless by itself. It is, however, very difficult to get a high closing pressure with lever-operated valves which are nothing more than check valves. A check valve is an obturating device in which the cone is simply held on its seat by the pressure of the fluid (in this case the boiler pressure).

However, experience shows this pressure to be quite insufficient and this is the explanation why quick-closing valves of simple construction always work badly when hard substances get in between the cone and the seat.

Fifth principle :

The valve cone must be pressed on the seat with the greatest possible force; this force should equal at least ten times the boiler pressure acting on the surface of the cone. The greater the closing force, the greater certainty there is that the valve will properly close, and any foreign matter lodged in the seat be crushed and pulverised.

6. *How is a blow-down valve to be protected from failure?*

Owing to the particular characteristics of locomotive service, all parts of the engine should be absolutely reliable.

Experience unfortunately teaches us that even the best designed and built equipment can get out of order or fail to work.

Sixth principle :

An absolutely essential requirement in a locomotive blow-down valve is that the enginemen can deal with any sudden failure. If, for example, the cone should fail to close automatically onto its seat, then it must be possible to close it by a screw-down spindle. In the case of locomotives for specially important work, a second closing device should be fitted between the blow-down valve and the boiler so that if anything really untoward occurred, such as part of a rivet head getting onto the seat, the blow-down valve could be put out of service entirely. This additional fitting must be so designed that it will work even after having been out of use a long time, and then cut off the blow-down valve completely. This is a very difficult condition to meet as with time the scale from the water builds up on the joints of this valve. Only one type of joint meeting these conditions can, therefore, be used.

7. *Should the track be kept free from the sludge discharged?*

As the sludge is blown down during running, i.e. under full boiler pressure, it is discharged at a very high speed. If allowed to discharge freely the jet would

(*) Chromium-steel (20 % of chromium), the hardness of which is increased by suitable heat treatment.

disturb the ballast and dirty the engine; the noise would, moreover, be most unpleasant.

Seventh principle :

The blow-down valve must have a fixed discharge pipe, with a self cleaning nozzle to brake the violence of the jet. The sludge can then be blown-down without any danger, whereas if there is no such device the jet of hot muddy water might hurt the enginemen or anyone nearby.

* * *

The above enumeration of some of the most important conditions a blow-down valve must meet shows that if it is to meet service requirements such a valve must be very carefully designed, and in doing so particular attention must be paid to the pecularities inherent in blowing down sludge, which we have dealt with in this note.

These points ought to be investigated by an organisation really well informed on the subject, as this is the only way the desired results can be obtained in practice.

[625 232 (.44)]

Construction of a light-weight three-coach articulated unit in the French Nord Railway Company's Works,

by Mr. CHATEL,

Ingénieur principal adjoint au service central des ateliers de machines, Compagnie du Nord français,

and Mr. YOLLANT,

Ingénieur chef du 2e arrondissement du matériel roulant, Compagnie du Nord français.

(*Revue Générale des Chemins de fer.*)

General.

Many attempts have been made in recent years to lighten railway rolling stock. A number of tests have been made in different countries but as a rule all that was done was to use high-tensile light alloys in place of steel, riveted construction being retained.

The results obtained in service on the French Nord Railway with the welded bodies, originated by this Company in 1924, were so satisfactory that there seemed to be no logical reason why light metals should not be used in the same way. We were fully aware of the difficulties to be overcome, but they were greatly reduced by close collaboration with the makers of high-tensile aluminium alloys, who introduced a magnesium-aluminium alloy having the characteristics given below.

In this coach, for safety reasons well justified under the circumstances, we have retained the steel frame although it is possible that at a later date we shall use light alloys in the underframe and headstocks.

We have, of course, endeavoured to lighten all parts of the vehicle by using when possible high-tensile light alloys and high-tensile steel in parts affecting safety, and by careful design as regards the various details.

The weight saving effected in the spring-borne part made it possible to use an articulated bogie between two bodies without overloading the axles.

The Hellemmes shops have designed and built on this basis the three-coach articulated rake carried on 4 bogies, as shown in figure 1.

Fig. 1. — General view of the rake.

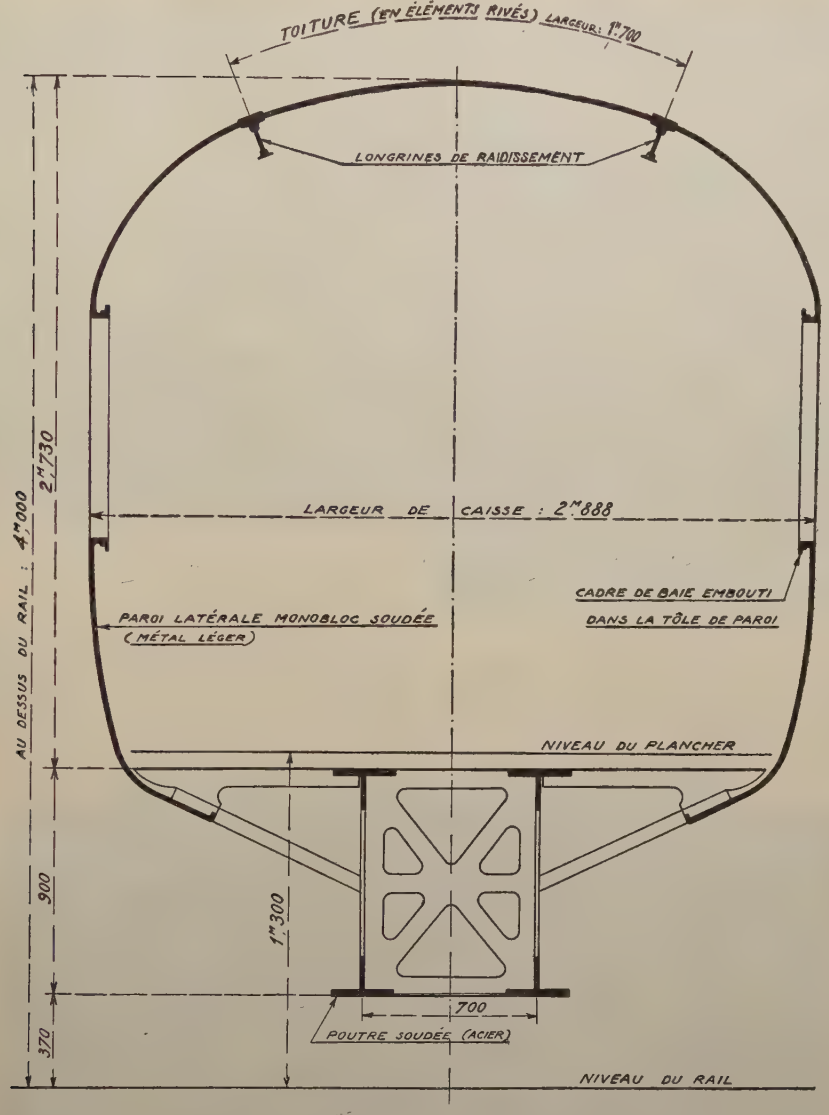


Fig. 2. — Cross section of a body.

Explanation of French terms:

Toiture... = Roof, of riveted sections 1.70 m. (5'6") wide. — Longrines de... = Longitudinal stiffening members. — Largeur... = Body width. — Paroi latérale... = Monoblock welded body side plate (light alloy). — Cadre de baie... = Light frame pressed in the body side sheeting. — Niveau du plancher = Floor level. — Poutre... = Steel welded girder. — Niveau du rail = Rail level. — Au-dessus du rail = Above rail level.

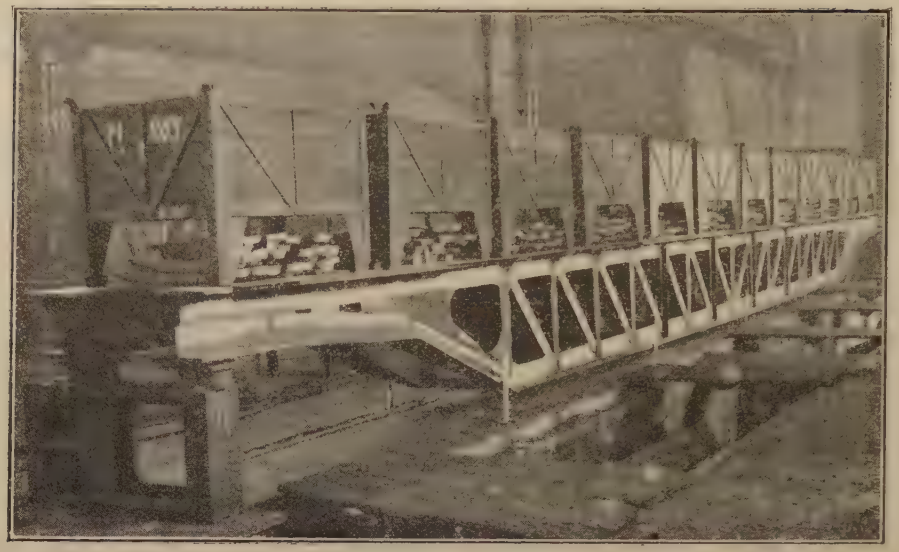


Fig. 3. — Frame main girder. Static test

Body framing.

Figure 2 is a cross section of the body. The latter consists of a trellis-girder frame of varying depth (fig. 3), on which is erected a body frame in light alloy.

The frame has been made strong enough to take the whole load without relying on the light alloys nor on any addition the body might make to the strength of the coach. In addition, the deflection of this frame under load was

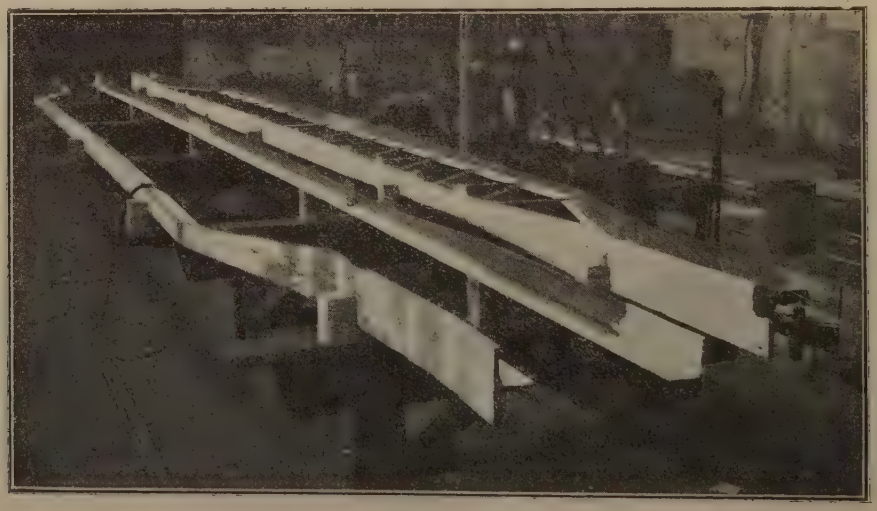


Fig. 4. — Shaped bottom flanges of trellis girder.

limited to a fixed amount so as to prevent excessive deformation in the body parts [30 mm. (1 3/16 inch) under a load of 30 tons uniformly distributed over the whole floor].

The design was based on this requirement. We were thus led to make the girder as deep as the constructional gauge and erection conditions would allow. The need to make it as light as possible resulted in the design, figure 4, which shows the variation in width of the flanges in relation to the depth, so as to obtain the desired moment of inertia in all sections.

The maximum deflection as first found graphically when designing the frame was 30 mm. (1 3/16 inch) under the conditions imposed. Statical tests carried out (fig. 3) confirmed these expectations.

The flanges of the girder are Grey sections cut in two along the centre line. The lower tees are bent as required to get the desired longitudinal section (figs. 4 and 5). The flanges are cut away as required.

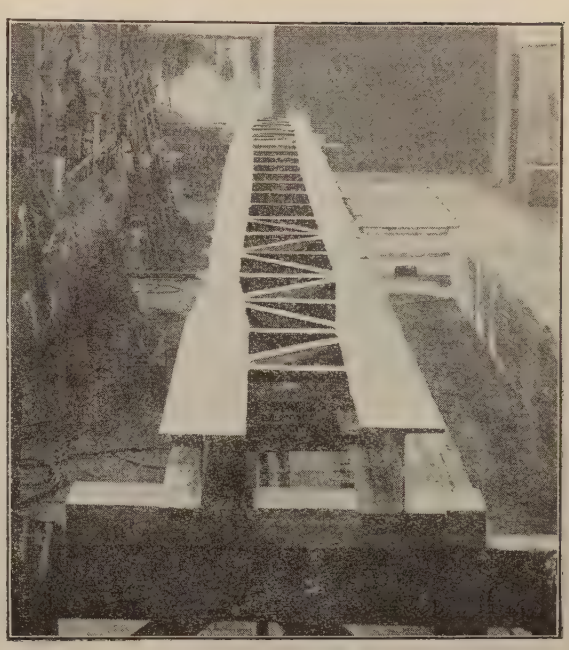


Fig. 5. — Cut-out top flanges of the trellis girder (looking from above).

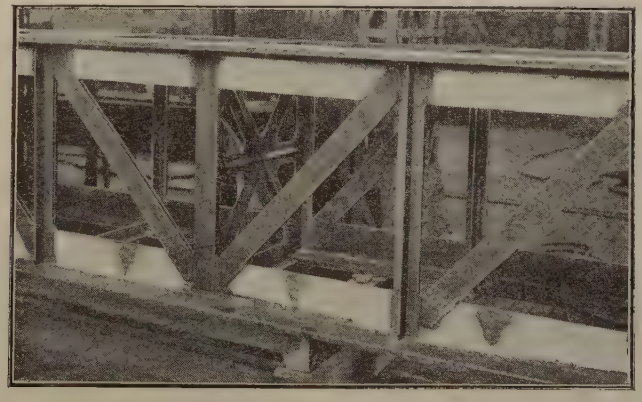


Fig. 6. — Trellis girder struts and diagonals.

The cross stays tying the two half girders together consist of two 3-mm. (1/8 inch) plate pressings spot welded (fig. 6).

Body construction.

The body resembles the tubular construction of the present steel coaches.

This body, 2.888 m. (7 ft. 6 5/64 in.) wide is formed of two solid-welded shells (fig. 7) forming the sides up to the roof longitudinal members. The roof is reduced to a centre plate 1.70 m. (5 ft. 6 in.) wide riveted in place after the two sides are located on the underframe.

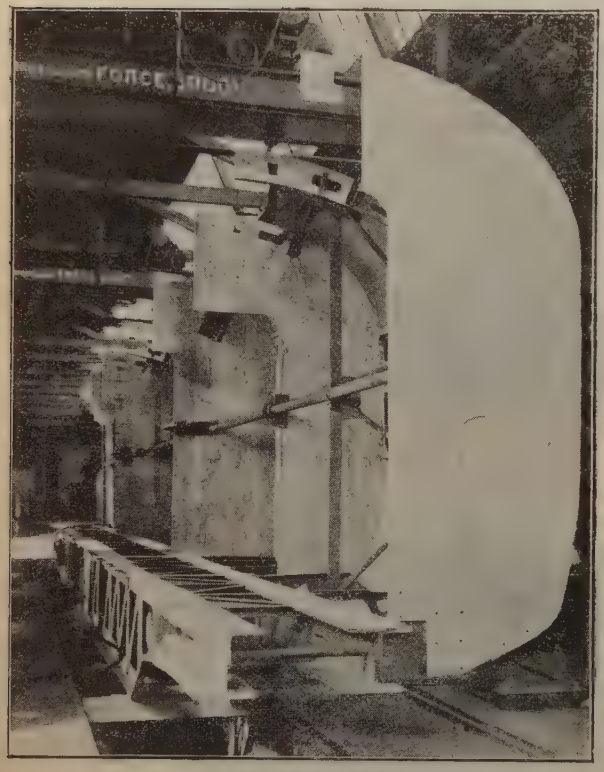


Fig. 7. — Body half-shells.

The light alloy used in the bodies was supplied by « Le Duralumin » Company and is known as *G7 metal;* it is an aluminium-magnesium alloy, containing 7 % of the latter component.

This alloy was chosen in preference to duralumin as it has good mechanical characteristics in the annealed condition. Obviously there could be no question of heat treating after welding parts at least 17 m. (55 ft. 9 in.) long.

The mechanical characteristics are :

Tensile strength R $\geqslant$ 36 kgr/mm² (22.8 Engl. t. per sq. inch);

Yield point E $\geqslant$ 18 kgr/mm² (11.4 Engl. t. per sq. inch);

Elongation % $\geqslant$ 18 to 22.

With such characteristics, a welded body was possible. We wanted to make a monoblock coach, but practical difficulties, which at present are unsurmountable, obliged us to rivet the roof and to limit welding to the sides, the parts that mattered.

After many tests, electric arc welding was adopted; this is the first time, we believe, it has been used on so large a scale.

The preparatory work involved was quite unusual, and in this connection readers are referred to the article by Mr. LANCRENON, the Chief Mechanical Engineer of the Nord Railway, in the September and October 1934 numbers of the *Revue de l'Aluminium.* This article can be summed up in a few words as follows :

a) We felt it desirable to strengthen the welded parts by ribs to make good the reduction in strength of the metal;

b) We found it necessary to preheat the parts to be welded, up to about 280° C. (536° F.);

c) We had to weld on the flat as the molten metal is extremely fluid.

In view of these conditions, the sides have to be mounted on pivoting jigs with heating stands as shown in figure 8.

The sides are built up in this way, section by section, into a unit 17 to 20 m. (55 ft. 9 in. to 65 ft. 7 3/8 in.) long according to the case, consisting of curved panels of 3.2 mm. (1/8 inch) sheet steel, 1.50 m. (4 ft. 11 in.) wide, between which are welded hooped stiffeners consisting of 60 × 60 × 6 mm. (2 3/8 in. × 2 3/8 in. × 1/4 in.) tees and 6-mm. (1/4 inch) sheet (fig. 9).

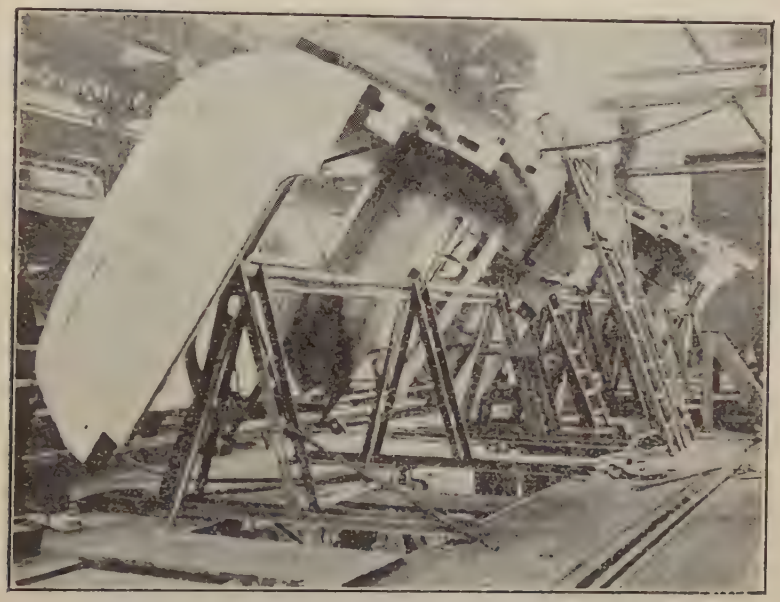


Fig. 8. — Erecting body sections on a pivoting jig.

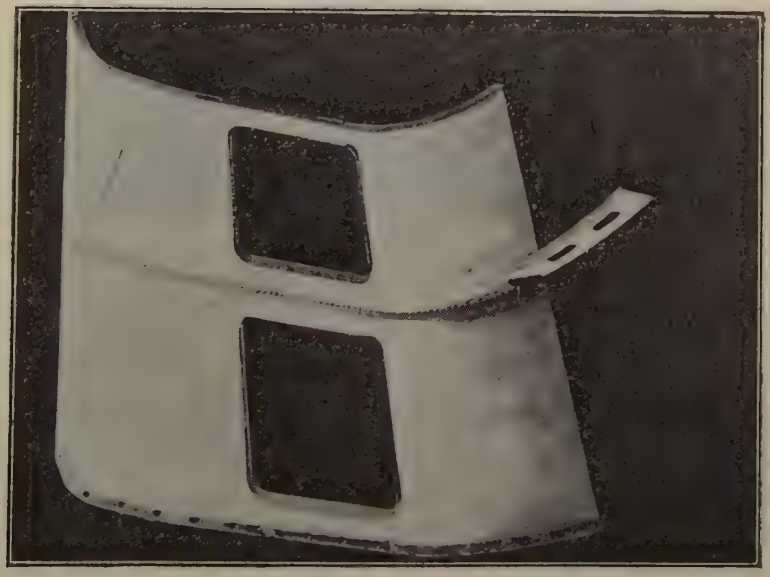


Fig. 9. — Body section with stiffening T.

Various fluxes were used extensively in this welding, but they are still not quite as good as they ought to be.

The body is secured to the underframe by brackets in two parts between which the hoops are gripped. These brackets and their braces in square tubing are made of steel.

The assembly is again electrically arc-welded to the frame.

All points where the light alloy and steel are in contact are coated with « neobitum »; this is a most important precaution which prevents corrosion due to electrolysis.

The window frames are pressings. The end doors are built up in four parts welded together.

The end pressings are strengthened by tees, the centre part consisting of a 6-mm. (1/4 inch) plate which forms a shock member.

The double sides at the vestibules into which the sliding doors disappear consist of 5-mm. (3/16 inch) plate, on the compartment side, and 3.2-mm. (1/8 inch) plate on the other.

It is absolutely essential that the welds should be scrubbed several times with hot water to prevent any subsequent chemical action between the flux and the metal.

Fig. 10. — Joint bogie.

Bogies.

Figure 10 shows a joint bogie. The frame has a triangulated X shape (see fig. 11) without any headstock. It is built of *Schneider*'s special *1.5 D. F. O.* steel plate.

This metal which is made in the electric furnace has the following mechanical characteristics :

Tensile strength R $\geqslant$ 60 kgr./mm^2 (38.1 Engl. t. per sq. inch);

Yield point E 42 kgr./mm^2 (26.7 Engl. tons per sq. inch);

Elongation A $\geqslant$ 18 %.

Its carbon content is under 0.17 % and it contains 1.5 % of nickel and 0.6 % of chromium.

This metal can be pressed and welded; we have consequently been able to apply to railway work the principle of *tubular* members used in automobile and aircraft construction.

Fig. 11. — Bogie frame.

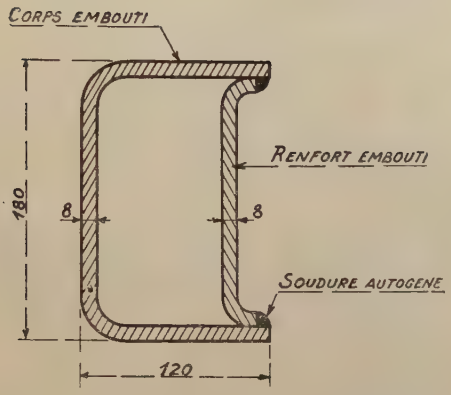


Fig. 12. — Section of bogie side member.

Note: Embouti = Pressed. — Renfort embouti = Pressed strengthening plate. — Soudure autogène = Autogenous welding.

Figure 12 gives the section of the centre part of the bogie frame in line with the elliptic springs.

The body bolsters have the same section.

The different details of the bogie (side frames, cross beams and diagonals) are assembled by electric welding with high-tensile electrodes.

The frame described weighs 780 kgr. (1 720 lb.) finished, whereas the present cast steel frame weighs 1 180 kgr. (2 600 lb.).

The bogie bolster has been designed on the same principles.

The bogie is also noteworthy by its entirely self-contained brake gear. Alpax cylinders are used with a lightened brake rigging, with brake shaft levers of 1.5 D. F. O. steel, and brake truss bars of high-quality nickel cast steel (Haine St. Pierre and Lesquin patent).

The spring gear is of the ordinary *Pennsylvania* type.

The equalising yokes deserve special mention as they are made of nickel-chrome-molybdenum steel with the following characteristics :

Tensile strength R $\geqslant$ 80 kgr./mm^2 (50.8 Engl. tons per sq. inch);

Yield point E $\geqslant$ 70 kgr./mm^2 (44.4 Engl. tons per sq. inch);

Elongation A $\geqslant$ 13 % and impact value $\rho \geqslant$ 9 kgrm./cm^2 (420 ft.-lb. per sq. inch) [on 10×10×55 mm. (25/64 in. × 25/64 in. × 2 3/16 in.) test pieces with a 5-mm. (13/64 in.) notch, broken in the Charpy pendulum testing machine].

The thickness of these bars was reduced to 20 mm. (25/32 inch).

The Isothermos axle boxes are also made of light alloy.

The bogie weighs 5 300 kgr. (11 680 lb.) without brake gear, and 5 900 kgr.

(12 235 lb.) complete. It is designed to carry 30 tons in ordinary service.

The use of the *Pennsylvania* type of bogie prevented us from lightening the bogie as much as we should have liked, but we did not wish to complicate the problem by designing a new bogie, and consequently were satisfied with an approximate solution.

Articulation of the bodies.

Figure 13 shows the design. The female centre piece A, shown in figure 10, is carried on the end of the body underframes and rests on the ordinary bogie center piece B supported by the spherical centre bearing C, which is isolated from the bolster beam by the *Spencer* rubber shock absorber S. The male centre piece D, solid with the other coach underframe, is pivoted in part A; a bushing E and a centre pin F, both of bronze, provide a smooth friction surface.

The centre pin passes through the whole joint with some play and is only a safety device.

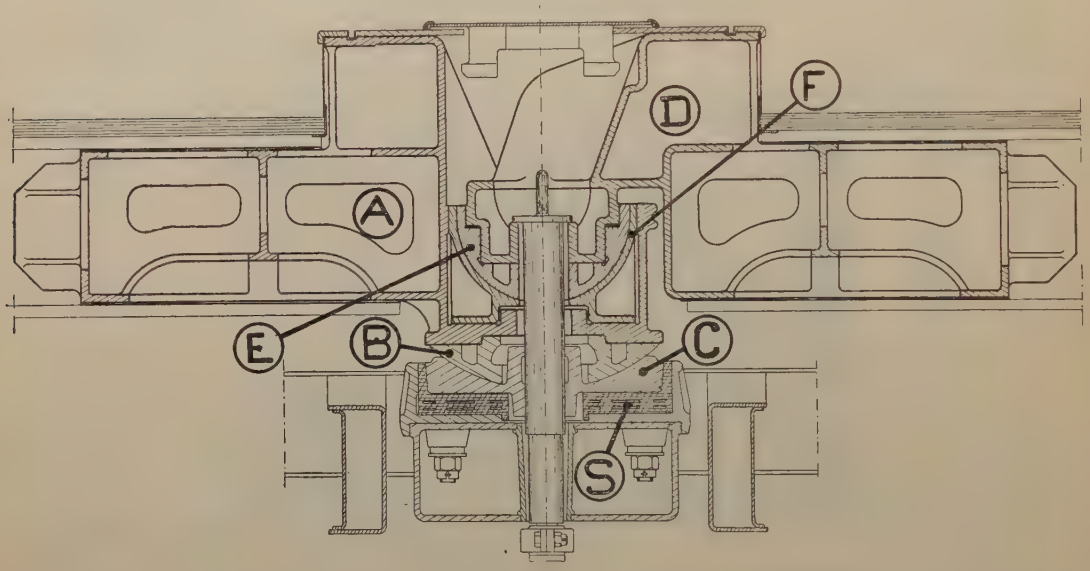


Fig. 13. — Detail of joint bogie centre (cross section).

The pivoting pieces A and D are the BS quality cast steel of the Standard Specifications.

Tests under static loads.

The body framing of each coach was subjected, before being covered in, to a test under increasing static loads.

We give below (fig. 14) a diagram showing the deformation found under a load of 30 t. (1 760 kgr. per m.) [29.5 Engl. tons — 1 182 lb. per lin. ft.) in the case of the intermediate body (top part) and under 35.2 t. (34.7 Engl. tons) — same rate of loading — for the end body (lower part)].

These tests showed that the body adds to the strength of the vehicle as a whole; under equal loads, the deflection of the intermediate body is only 17.1 mm. (11/16 inch.) whereas that of the frame

girder of the same body by itself is 30.6 mm. (1 7/32 inches). The end body gave figures of 27 mm. (1 1/16 inches) and 13.3 mm. (33/64 inch.) respectively.

No undue deformation was recorded in the light-alloy parts. Nonetheless we

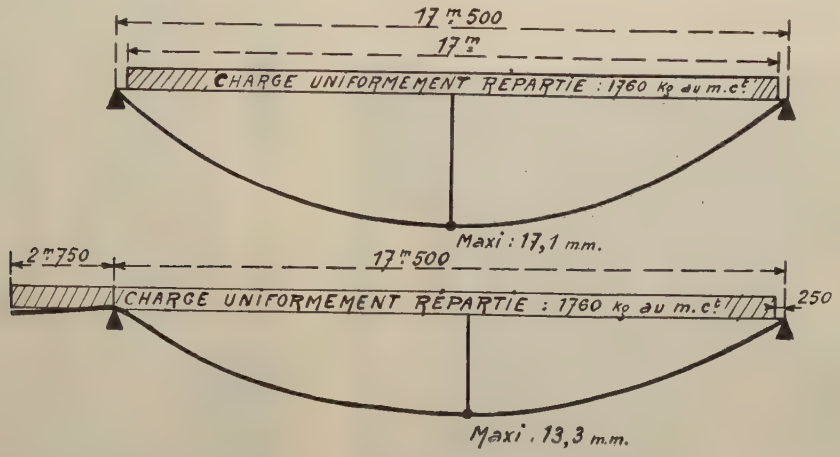

17 m 500
17 m
CHARGE UNIFORMEMENT REPARTIE : 1760 kg au m.c.
Maxi : 17,1 mm.
2 m 750
17 m 500
CHARGE UNIFORMEMENT REPARTIE : 1760 kg au m.c.
250
Maxi . 13,3 m.m.

Fig. 14. — Deflection curves, with body in place.

Note: Charge... = Uniformly distributed load.

felt it desirable, after systematic examination of the work, to strengthen some parts in the top of the roof.

Fitting out.

Floor. — The floor is built up of Plymax panels (plywood panels faced with a zinc sheet above and with an aluminium sheet underneath, 26 mm. (1 1/32 inches) thick and weighing 30 kgr. per m² (6 lb. per sq. foot). These panels are assembled with lap joints and are fixed to the frame members by means of steel bolts through aluminium cover plates, the steel nuts being spot-welded to the underframe. To prevent aluminium coming into contact with the steel the parts are coated with a coat of « neobitum » paint. The floor is covered with linoleum.

Doors. — The entrance doors made of light alloy are of the « Suburban » type now in service. The foot board brackets are Alpax with a wood step and a light alloy riser. The two sliding leaves (Faivelay system) are opened simultaneously by means of the right and left-hand threaded spindle to which they are attached. They are easily opened and shut, the rollers moving on a ball-bearing runway. The doors can be closed by the guard by means of a pneumatic operating gear carried on the frame under the floor.

The compartment and vestibule doors (fig. 15) slide in the cross partitions and are designed on the same lines as the entrance doors.

Windows. — Drop lights are provided in the vestibules. The compartment framed lights (fig. 15) are divided in two parts, the top portion slides up and down and is fitted with Klein side balancers, to hold it in the desired position. This arrangement is perfectly weathertight and absolutely prevents water getting between the outside body sheeting

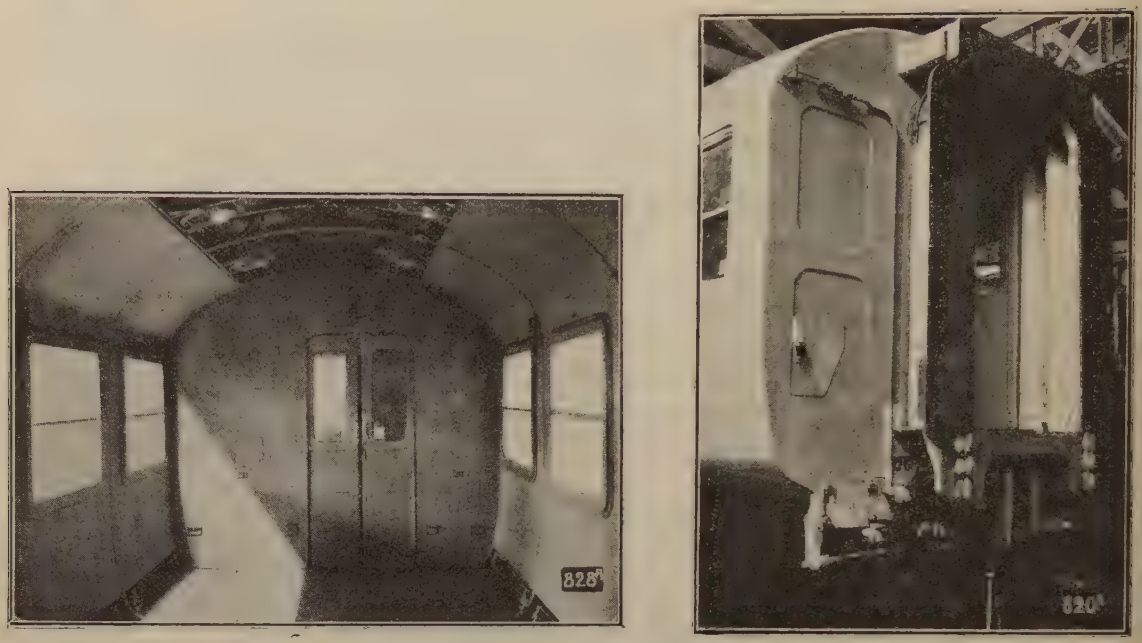


Fig. 15. — Entrance and vestibule doors.

and the interior linings. The door frames are made of light alloy and the inside and outside mouldings of Alpax.

Seats (figs 16 and 17). — The three bodies are fitted up for third-class traffic. The wooden seats (ash and « dau »-wood) are assembled on each side of a centre gangway. All wooden parts have been lightened by hollowing them out, and are glued together. The benches seat 6, 4, 3, and 2 passengers and weigh 27, 20, 18 and 15 kgr. (59.5, 44, 39.7 and 33 lb.) respectively. The legs are made of Stellanium tubes, secured in bearings attached to the floor and the seat. The hand grips are made of aluminium.

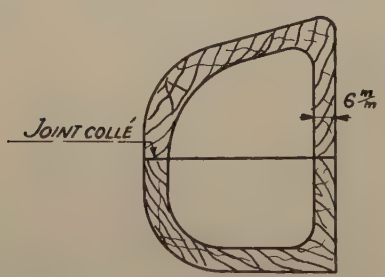


Fig. 16. — Section through seat frame.

Insulation. — The different parts of the rake have been insulated in different ways. The body sheeting of one of the end bodies has been lined out on the inside with « Expansit » brand cork panels encased in jute canvas, and pasted on with zinc white. The intermediate body has been lined out in the same way, but « Siccolin » glue has been used instead of zinc white. The other end body has been insulated by spraying a mixture of asbestos flock and glue by means of an air gun.

Inside lining. — G. 7 metal sheets 1.6 mm. (1/16 inch) thick have been used.

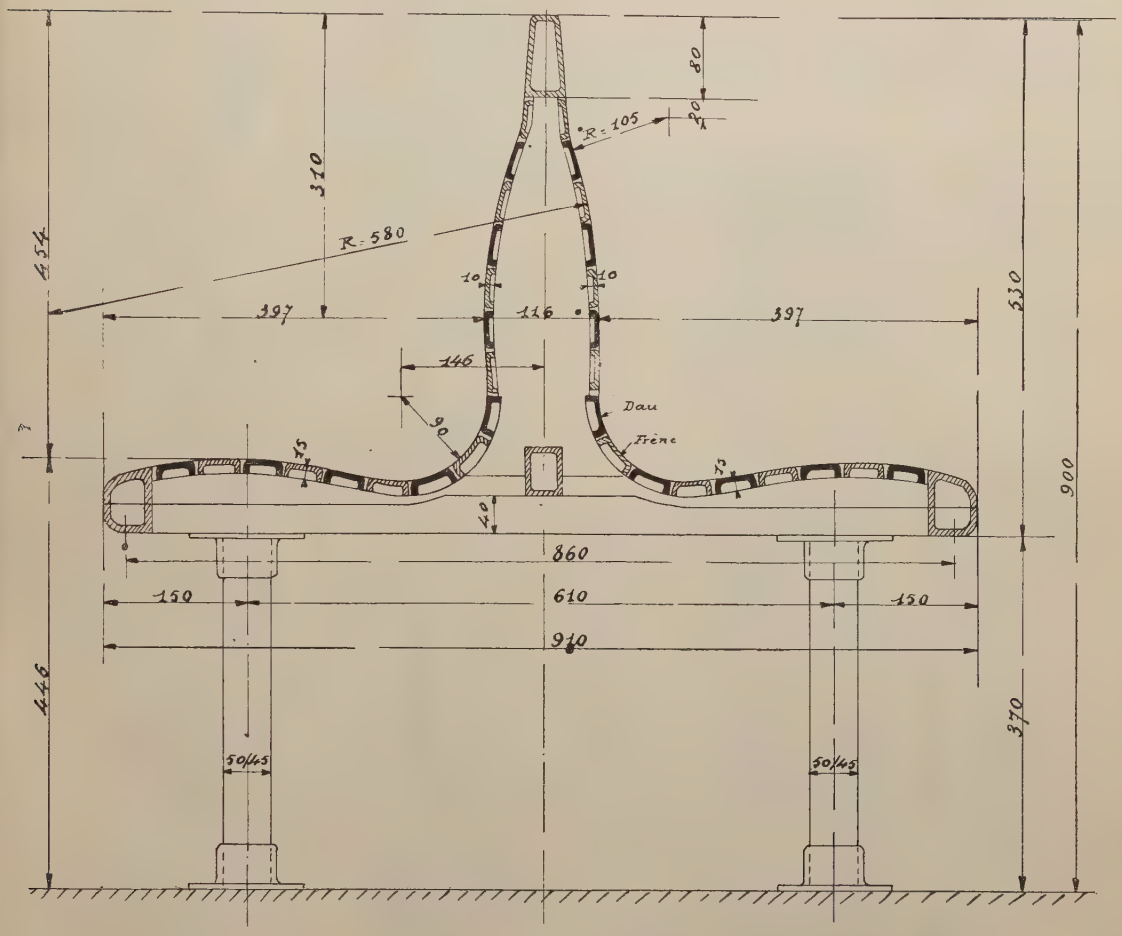


Fig. 17. — Section through seat.

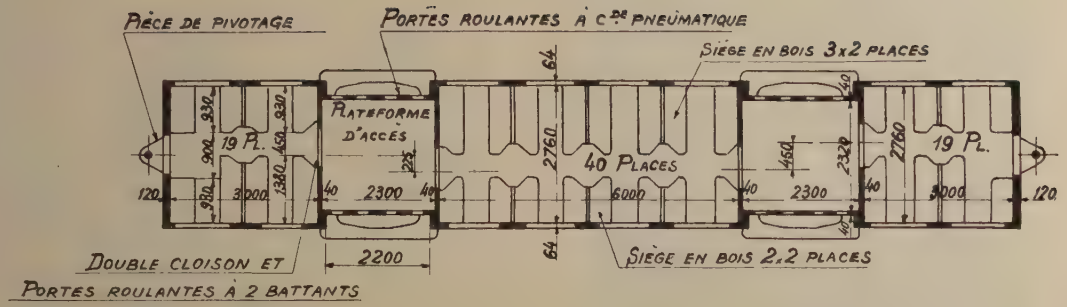
They were coated with insulating material in the same way as the outside sheeting. The sheeting is held to the body framing by joint strips pulled up to the body framing by duralumin screws.

Lighting. Reversing. — The vehicles are electrically lighted as one unit. Two ceiling lights per section, one on each side of the centre line, are fitted in the roof. The glass bowls are held to the ceiling by a bayonet fastening and a retaining spring.

The electric-lighting and reversing cables are carried on the frame girders on duralumin brackets and are covered in by aluminium sheet.

Heating. Brakes. — The steam heating equipment includes horizontal radiators made of light metal, the lower portion being recessed into the body sides (fig. 15). Each of the vestibules can be heated by two seven-section radiators of the ordinary type.

The steam heating pipe is under the



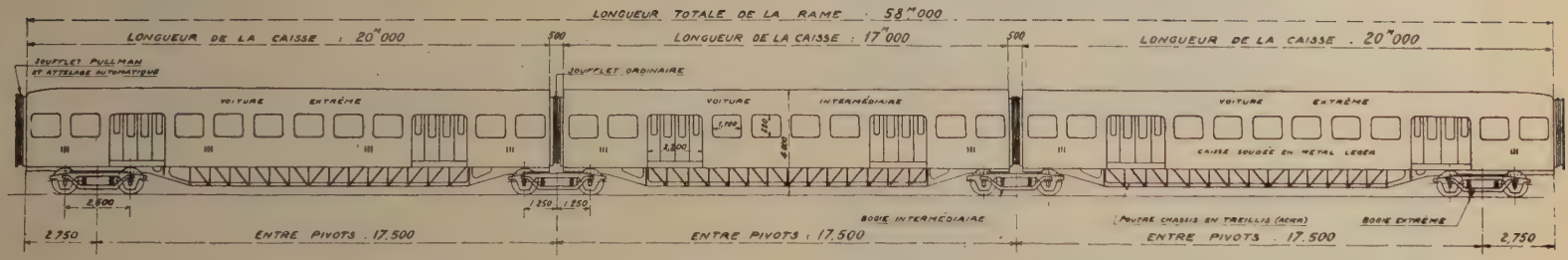


Fig. 18. — General diagram.

Explanation of French terms:

Pièce... = Articulated coupling. — Portes... pneumatiques = Air-operated sliding doors. — Siège... = Wooden seats. — Plateforme d'accès = Entrance platform. — Double... battants = Double partition with sliding doors in two parts. — Longueur totale de la rame = Total length of the rake. — Longueur de la caisse = Body length. — Soufflet... automatique = Pullman bellows and automatic coupling. — Soufflet ordinaire = Ordinary bellows. — Voiture extrême (intermédiaire) = End (joint) bodies. — Bogie extrême (intermédiaire) = End (joint) bogies. — Entre pivots = Between centres.

floor, and the part on which the pipes are branched to the radiators is made of almasilium, the rest being of steel. The straps carrying the pipes are made of duralumin whilst the stirrups securing the branch pipes and the sleeves joining the steel and almasilium pipes are galvanised steel. The sockets and tees on the light metal pipe are made of duralumin.

The brake pipes are steel and are either welded to the underframe members or fastened by flanges on brackets welded to the frame.

Vestibules. — Pullman vestibule bellows are fitted at the outer ends of the rake (fig. 15) and bellows of the usual type between the bodies.

Miscellaneous. — The luggage racks fitted longitudinally above the drop lights and transversely above the doors in the compartments are made up of perforated aluminium sheet. The brackets are made of Alpax.

Boyriven ventilators made of light alloy are used to ventilate the vehicles.

Painting. — The outside sheets, after being degreased with petrol and scoured with sand paper were given :

a coat of special lorry yellow for aluminium alloy,

a coat of lead undercoating,

6 coats of grey ground coating,

3 coats of stopping for the welds and hollows, rubbed down between each coat,

a coat of green undercoating, and

2 coats of enamel.

The bogies were given a coat of red lead and one of train black.

The frame after degreasing, scaling, and wire brushing, was given one coat of red lead, and one of train black..

The inside painting of the coaches consisted of :

removing all grease from the sheeting with petrol and cleaning off with sand paper,

2 coats of lorry yellow,

puttying up with varnish and priming partitions and sand-papering partitions,

3 ground coats on the partitions and sides, and lastly,

2 coats of enamel.

Weight.

Comparison with the present all-steel vehicles.

The table below gives the weights of the present steel stock and that of the bodies of the light rake. In addition we have shown the estimated weight of an imaginary vehicle of the same seating capacity as the steel vehicle used for comparison.

This table shows that the estimated saving in weight is in the body, the weight of which has been reduced from 10 500 to 3 730 kgr. (from 23 150 to 8 220 lb.) for equal capacity; this lightening represents 16 % of the weight of the steel vehicle taken as 43 t. (42.3 Engl. tons).

Nor is the weight saving obtained by articulating the rake to be overlooked; there is first a 9 % saving by reducing the number of bogies, and then 6 % due to the simpler intermediate coupling, or 15 % of secondary savings. This is the more valuable as, if the primary lightenings are expensive owing to the cost of light alloys (both as regards the materials and labour) the secondary savings are not, as they effect an appreciable lightening which partly compensates the other costs.

The sum up, the weight of the unit is 75 t. (73.8 Engl. tons). The two end

Parts.	Weight, kgr. *(lb.)*.				Lightening, % of total.
	Steel coach, 98 seats.	End body, 20 m. (65′ 7 3/8″) long.	Middle body, 17.50 m. (57′ 5″) long.	Average for imaginary vehicle, 98 seats.	
Body	10 500 *(23 150)*	3 500 *(7 715)*	3 330 *(7 340)*	3 730 *(8 220)*	16
Girder frame	7 100 *(15 650)*	7 000 *(15 430)*	5 600 *(12 345)*	7 050 *(15 540)*	...
Buffing and draw-gear .	2 400 *(5 290)*	650 *(1 430)*	nil ...	440 *(970)*	4
Bellows	1 500 *(3 305)*	850 *(1 870)*	200 *(4 410)*	680 *(1 500)*	2
Fittings	7 750 *(17 085)*	6 200 *(13 670)*	5 570 *(12 280)*	6 420 *(14 150)*	3.5
Bogie—Brake	13 570 *(29 915)*	5 950 × 4 *(13 120×4)*	whole rake	8 600 *(18 960)*	12
Total . . .	43 000 *(94 395)*	75 000 *(165 345)*	whole rake (1)	26 920 *(59 350)*	37.5

(1) See diagram, figure 18.

bodies have 98 seats (as in the steel stock) and the middle body 78 or a total of 274. The tare weight per seat is about 275 kgr. (606 lb.).

The total reduction in weight relatively to the all-steel stock with a weight per seat of 440 kgr. (970 lb.) is therefore 37.5 %.

MISCELLANEOUS INFORMATION.

[625. 143.1 (.47)]

1. — New Russian standard rail.

(*The Railway Gazette.*)

Almost the first problem confronting the U. S. S. R. railway authorities in carrying out the grandiose scheme of transport reorganisation proposed by the second Five-Year Plan was the introduction of a rail suitable for axle loads up to 25 t. (24.6 Engl. tons). After a full consideration of practice in Europe and America, taken in conjunction with Russian experience, the desideratum was somewhat modified, and an entirely new rail section evolved, which, although weighing only 91.5 lb. per yard (45.3 kgr. per m.), is now being used under 23-tonne axle loads.

Viewed according to existing and prospective traffic, the railway system of the U.S.S.R. was divided by the People's Commissariat for Transport into three categories, the tracks of which were to meet the following requirements :

Class I. — 25-tonne axle load.

Class II. — Standard 0-10-0 locomotives with 18-tonne axle load and a possible future increase to 20 tonnes.

Class III. — 2-6-2, 4-6-2, and 4-8-0 locomotives with axle loads up to 18 tonnes.

For over two years a rail weighing 88 lb. per yard (43.6 kgr. per m.) has been used on certain Class I lines, but as less than 2 % of the total mileage is laid with this section it cannot be regarded as a standard. The heaviest rail which could hitherto be regarded as a standard on the Soviet system scales 78 lb. per yard (38.6 kgr. per m.), and according to certain calculations it was believed that this rail could carry axle loads of 20 tonnes if the sleeper spacing was reduced to 21.5 inches (55 cm.).

After making numerous theoretical investigations, in the course of which it was found that, for Russian conditions, the maximum axle load in tonnes which could be carried was roughly equal to half the weight of the

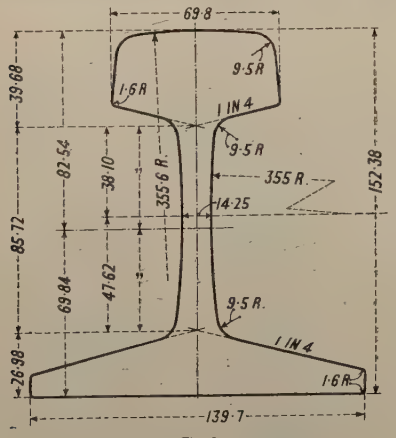


Fig. 1

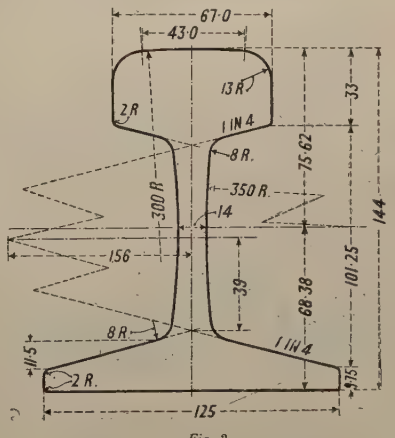


Fig. 2

rail in kgr. per metre, a new rail weighing 101 lb. per yard (50 kgr. per m.) and suitable for axle loads up to 27 tonnes, was designed under the direction of Ing. B. N. Sergeiev. In 1931 this design was proposed as the standard for Class I railways, but as the necessity of a 27-tonne axle load was not pressing, this section was never rolled. The design is still available for future use, and its proportions are shown in figure 1.

To meet the requirements of a 23-tonne axle load, the Central Institute of Scientific Research got out the design shown in figure 2, and this was adopted definitely as the standard and is now in extensive use. The main point of difference between this rail and the types previously in use are the curved instead of straight contour of the web, and a straight incline of 1 in 4 on top of the flange and beneath the head, in place of two or three different tapers. The continuous slope of the top of the flange is of advantage from the point of view of rolling, and also metallurgically because of the equalisation of the amount of metal in the head and flange of the rail. By adopting a section with a continuous slope, it was found possible to reduce slightly the thickness of the flange, and as the slopes of the flange and the underside of the head are the same, the design of the fishplates is simplified.

When the design was being evolved, consideration was given to certain German claims that the use of a head wider at the bottom than at the top (a feature incorporated in the design of the 101-lb. rail) would result in less wear, owing to the greater area of contact between the rail and the flanges of the wheels. The Russian engineers, however, held that this was true only in the case of static load, and that where dynamic loads were the important factor, as they are in railway practice, the increased area gave greater slippage. In support of this it is stated that in North America the least wear has been experienced with rails having the underside of the head cut away. In such proportions as the relation of the flange width to the height of the rail, the new standard section does not differ markedly from modern practice throughout the world.

[621. 132.5 (.44)]

2. — New three-cylinder simple 2-10-2 goods locomotive, Alsace-Lorraine Railways.

(*The Railway Gazette.*)

The accompanying diagram drawing shows the general arrangement of a three-cylinder, simple 2-10-2 locomotive at present building in the workshops of the Alsace-Lorraine Railways at Grafenstaden.

The principal dimensions are as follow :

Cylinders (3), diam.	575 mm.	(22 5/8 in.).
Cylinders, stroke	720 mm.	(28 3/8 in.).
Coupled wheels, diam.	1 500 mm.	(4 ft. 11 in.).
Bissel wheels, leading, diam.	850 mm.	(2 ft. 9 1/2 in.).
» trailing, diam.	1 050 mm.	(3 ft. 5 1/4 in.).
Tender wheels, diam.	1 050 mm.	(3 ft. 5 1/4 in.).
Boiler working pressure	20 hpz.	(290 lb. per sq. in.).
» heating surface, tubes and flues	220.07 m²	(2 367.9 sq. ft.).
» » firebox	25.12 m²	(270.3 sq. t.).
	245.19 m²	(2.638.2 sq. ft.).
» » superheater	101.0 m²	(1 086.8 sq. ft.).
Total	346.19 m²	(3 725.0 sq. ft.).

Grate area	5.0 m²	(53.8 sq. ft.).
Wheelbase, rigid	4.890 mm.	(16 ft. 0 9/16 in.).
» total engine	12.180 mm.	(39 ft. 11 5/8 in.).
Weight of engine in working order	133.6 t.	(131.5 Engl. tons).
Adhesive weight	100 t.	(98.4 Engl. tons).
Tender, weight in working order	52.0 t.	(51.1 Engl. tons).
Water capacity	25 m³	(5 500 Br. gall.).
Fuel capacity	6.8 t.	(6.7 Engl. tons).
Tractive effort at 85 % boiler pressure, including booster	48 560 kgr.	(107 075 lb.).

The boiler barrel plates are of nickel steel 22 mm. (7/8 inch) thick. The front tube-plate and outside firebox wrapper plate are also of nickel steel, and a steel firebox is used, with stays of mild steel. A rocking grate is fitted, and the grate area is 2.4 m. by 2.1 m. (7 ft. 10 1/2 in. by 6 ft. 10 11/16 in.). The single-leaf firedoor is pneumatically operated.

The distance between tube plates is 5.905 mm. (19 ft. 4 3/8 in.), and there are 138 tubes of 50 mm./55 mm. (1.968 in./2.165 in.) diameter, and 35 flues of 140 mm./148 mm. (5.511 in./5.825 in.) diameter. The superheater, with 35 elements 31 mm./38 mm. (1.220 in./1.496 in.), is of the separate-chamber header type with multiple valve regulator. Boiler and cylinders are lagged with Newallite, and the equipment includes O.C.E.M. standard safety valve, Alsace-Lorraine standard steam fittings, two Boizard water level gauges and one test cock, type U.1.-O.C.E.M. injector, A. C. F. I. feed water heater, and Delmar smoke tube cleaner.

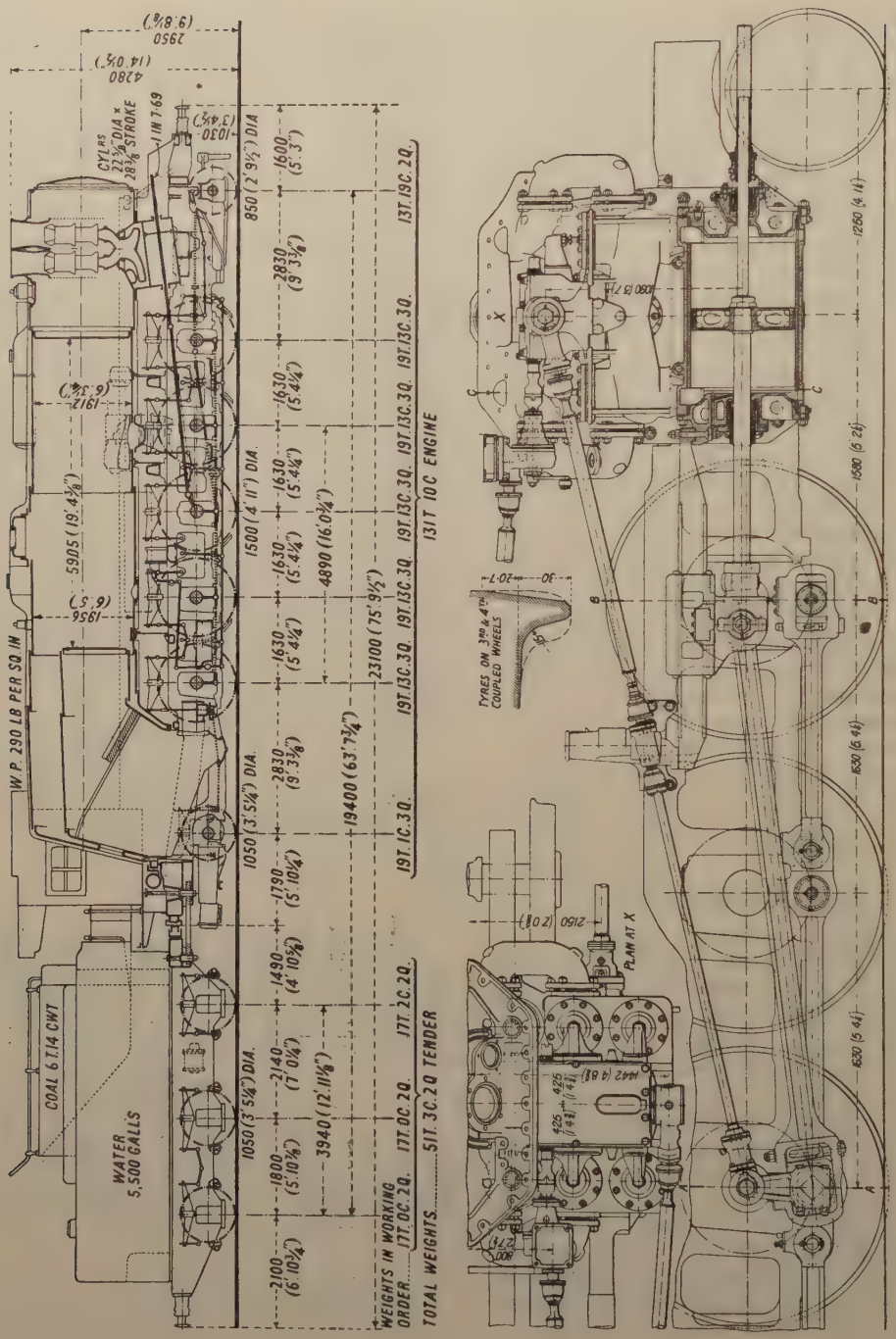
Frame and other details.

The rolled bar frames are 140 mm. (5 1/2 in.) in thickness. The front coupling is of standard type, the rear coupling of the O.C.E.M. type with central drawbar and safety drawbars, and the extended footplate of the Est type. The rim thickness is reduced in the tyres of the wheels on the third and fourth coupled axles, and the machine is capable of running over curves of 112 m. (367 ft.) radius. A booster is fitted on the trailing bissel, which has outside journals, and the leading bissel is link controlled. Steam distribution is by poppet valve on the Caprotti system, and a Kylchap variable double blast pipe is used, with two chimneys. Triplex and Duplex pressure gauges are used. Wakefield mechanical lubrication is provided for the cylinders and for the axle-boxes of the coupled wheels. The compressed air brake is of the Westinghouse automatic and direct type, and other features of the equipment are the bi-compound air pump, Leach-Viloco compressed air sanding gear, steam heating, Flaman speed indicator, and A.C.F.I. speed indicating and recording apparatus.

The weight of the engine, empty, is 121 t. (119.1 Engl. tons), and that of the tender, empty, is 19.6 t. (19.3 Engl. tons).

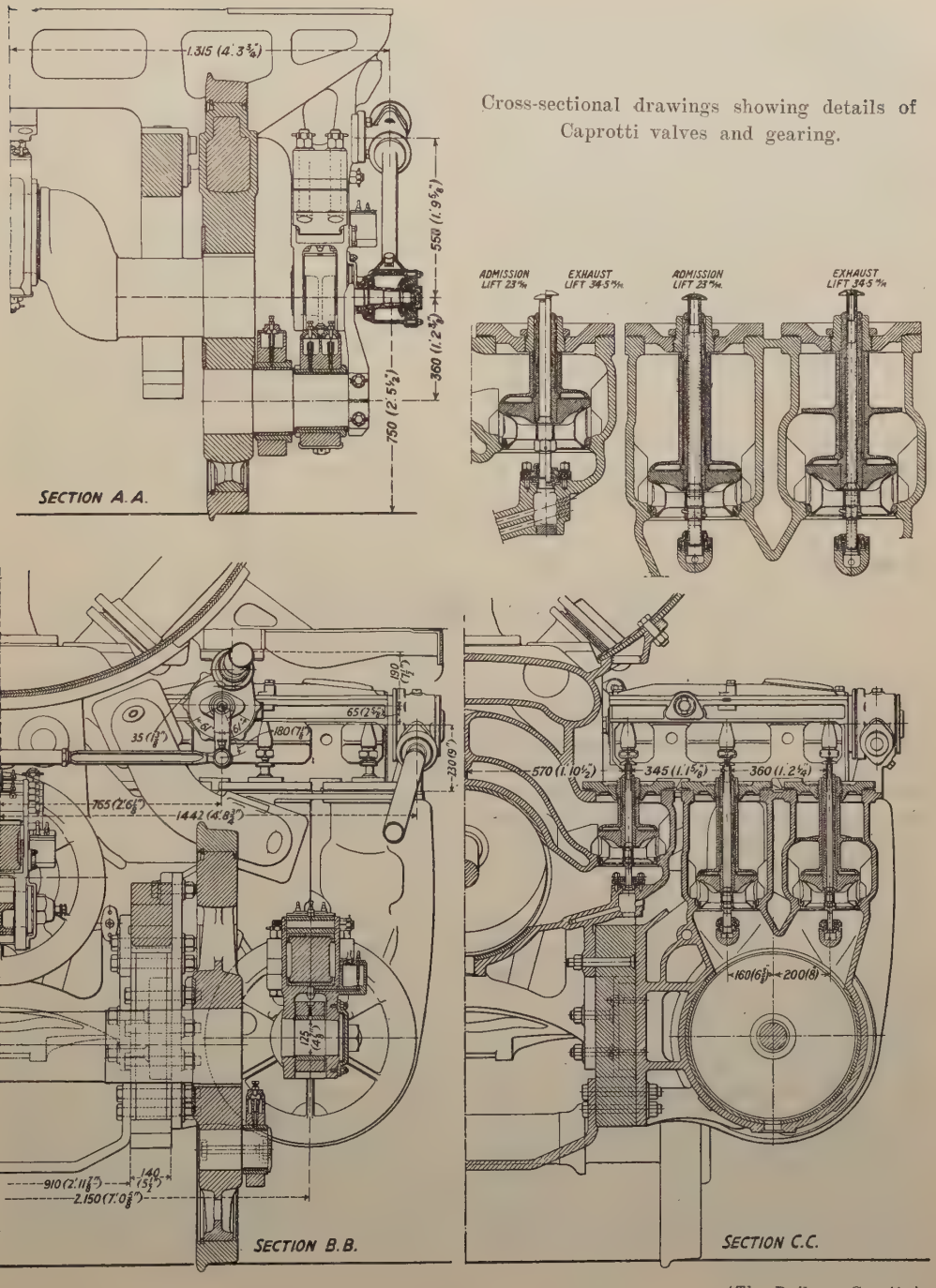
The design of this engine has been developed by the Office Central d'Etudes de Matériel de Chemin de Fer (O.C.E.M.), and details of the Caprotti valve gear are shown in the accompanying diagram. Two cam boxes are used, each of which controls the inlet and exhaust valves of an outside cylinder and one inlet and one exhaust valve of the inside cylinder. As the inlet and exhaust valves of the inside cylinder are arranged diago-

Profile of lines to be worked over by the new locomotive.


W.P. 290 LB PER SQ IN
CYLRS 22½" DIA x 28⅜" STROKE
1 IN 7·69
COAL 6 T. 14 CWT
WATER 5,500 GALLS
TYRES ON 3RD & 4TH COUPLED WHEELS
PLAN AT X
WEIGHTS IN WORKING ORDER... 177.0C.2Q. 177.0C.2Q. 511.3C.2Q TENDER
TOTAL WEIGHTS... 197.1C.3Q. 197.13C.3Q 197.13C.3Q 197.13C.3Q 197.13C.3Q 197.13C.3Q 131 T 10C ENGINE
177.2C.2Q.
137.19C.2Q.

General arrangement with details of Caprotti valve gear transmission mechanism.

(*The Railway Gazette.*)



Cross-sectional drawings showing details of Caprotti valves and gearing.

(The Railway Gazette.)

nally opposite the others, the cam boxes are interchangeable between right and left hand side. The cylinder design incorporates advantages which are protected by a Caprotti patent. The valves are of the springless balanced type similar to those used on the S. 16 Class 4-6-2 engines of the Alsace-Lorraine Railways. The driving gear is of the outside type and taken on each side from a return crank, the rotary motion being transmitted by shafts fitted with universal joints.

Operating conditions.

The engines have been designed to work heavy freight trains on the Thionville-Völklingen, Thionville-Audin-le-Roman, and Thionville-Luxembourg lines, which, as will be seen from the profiles reproduced, are heavily graded, and contain curves and reverse curves of 500 m. (1 640 ft.) radius on the gradients.

As the adhesive weight of the engine is 100 t. (98.4 Engl. tons) and the tractive effort can be increased by the booster, it is expected that it will haul a load of 1 700 t. (1 673 Engl. tons) at a speed of 20/24 kilometres (14.9 miles) per hour, over 1 in 91 gradients.

It will thus be seen that the work to be demanded of the new locomotive is of a heavy character and this it should be well capable of performing, as will be appreciated from a perusal of the proportions and other characteristics enumerated above. With a boiler pressure of 290 lb. per sq. inch., grate area 53.8 sq. ft., adhesion weight close upon 100 tons, distributed over ten coupled wheels, and mean theoretical tractive effort without booster, of 107 075 lb., the engine is well adapted in every way for the purpose in hand.

[621. 33 (.44)]

3. — The Paris-Le Mans electrification.

(*Electric Railway Traction*, Supplement to *The Railway Gazette*.)

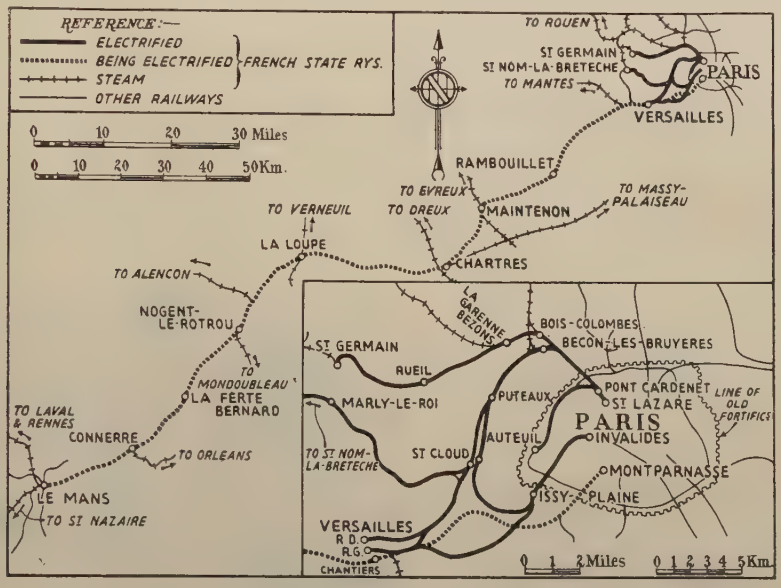
Following the recommendations of the Marquet plan, announced by the French Government in 1934 to assist in relieving unemployment by large public works schemes, the French State Railways are proceeding with the electrification of the Paris-Le Mans main line at a cost estimated to be 403 million fr., of which 175 million fr. are to be expended in the purchase of rolling stock. The other 228 million fr. do not include the cost of modifications to the approaches to Montparnasse, but cover civil engineering works down the line. The electrification is being carried out on the French standard 1 500-volt d.c. system, with overhead contact lines.

Power is to be supplied from the Paris steam plants and from the hydro-electric stations in the Dordogne, but the feeder voltage to the substations varies a good deal. At Le Mans the substation is close to an existing transformer station, and will be fed with three-phase current at a tension of 33 kV.; onwards to Chartres the substations will receive 90 kV. current from two parallel feeders, one from Eguzon, the main transforming station of the Dordogne plants, and the other from Chaingy, near Chartres, a transforming station of the Paris steam network. Between Chartres and Versailles the high-tension supply is at 60 kV. from the steam power plants, and the two substations located between Versailles and the Montparnasse terminus will be extensions to existing substations of the State Railways' Paris suburban lines.

There are eleven automatically-operated substations over the 131 miles from Paris to Le Mans, spaced at distances varying from 11 to 15 1/2 miles. An endeavour was made to locate them at railway stations as far as possible, and they are situated (as shown in the accompanying map) at Ouest Ceinture, Porchefontaine, La Verrière, Gazeran, Jouy, St. Aubin-St. Luperce, La Loupe, Nogent le Rotrou, La Ferté-Bernard, Pont de Gennes, Le Mans. The first two substations have a capacity based on the passage of 12 trains an

hour, and in each are installed three groups of 2 750-kw. mercury arc rectifiers, one of which is normally in reserve. The remaining nine substations each have two 2 000-kw. rectifier sets with room for the installation of a third should this be required in future.

The overhead line construction, now being erected, is of the semi-rigid catenary type used on the Paris-Orleans electrified lines. The contact wire is of hard copper, 12.2 mm. in diameter; the main catenary is of cadmium bronze 14 mm. in diameter, and the auxiliary catenary of copper 11.5 mm. in diameter. The normal span between the masts is 206 feet and on curves sharper than 2 300 feet radius, 118 feet. The distance between the stringers averages 14 ft. 9 in. The maximum tension in the main catenary is 5 100 lb., in the auxiliary catenary 2 750 lb., and in the contact wire 3 750 lb. The presence of this



Map of Paris-Le Mans and Paris suburban lines of the French State Railways.

overhead construction has involved the rebuilding of numerous bridges and stations, and opportunity has been taken to remodel the whole or part of the layout at certain points, notably at Clamart, Sèvres, Trappes, Chartres, and Le Mans, and at Rambouillet, the terminus of the suburban services. When the present quadrupling between Clamart and Porchefontaine is finished, the State Railways will have four electrified tracks from Paris as far as Trappes, 17 miles. Large yards at Montrouge-Châtillon, Vaugirard, Trappes-Triage, Chartres, Le Mans, and Versailles are to be electrified also, making a total mileage electrified of 435 compared with the 131 route miles.

The motive power required is to be of four types, *viz.*, express locomotives with a maximum permissible speed of 93 m.p.h.; general service locomotives with a top speed of 60 m.p.h., suitable for *trains-omnibus*, long-distance night trains which are slower than the day-time expresses, and goods trains; multiple-unit trains with a top speed of 60 m.p.h. for service between Paris and Chartres; and light motor coaches with a top speed of about 60 m.p.h. for stopping services between Chartres and Le Mans. It is possible that a

fifth type will be introduced in the form of a small number of light-weight high-speed motor coaches with a top speed of 93 m.p.h. for a special direct service between Paris and Le Mans.

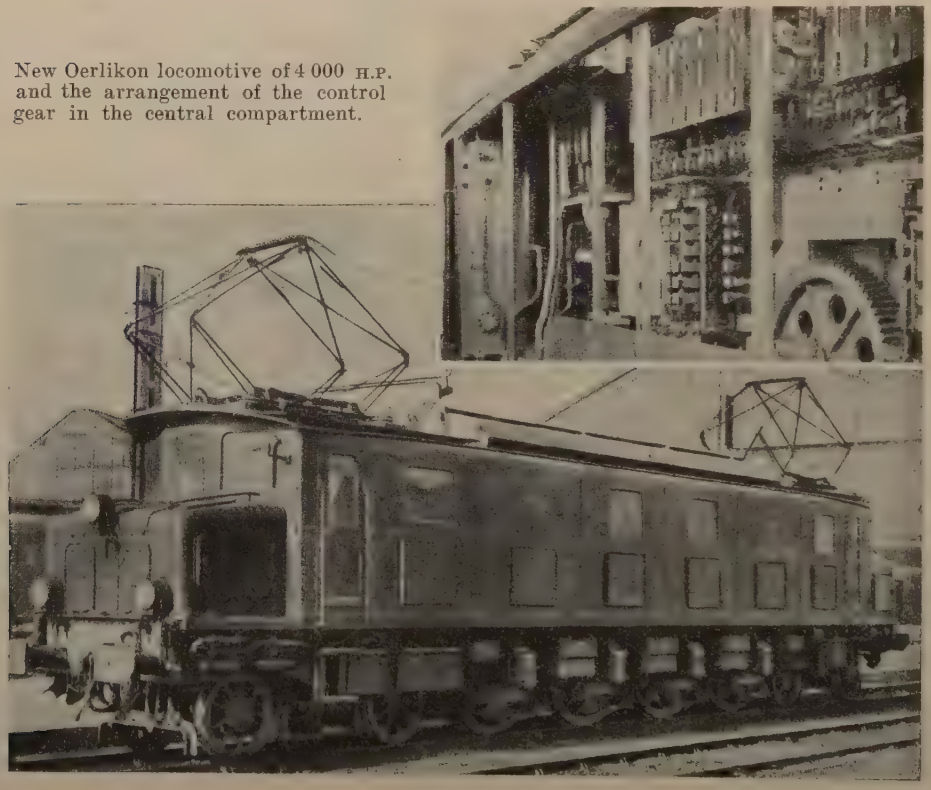
Both locomotive designs are to be based on the types operating on the Paris-Orleans electrified lines. The express units will be of the 2-Do-2 type with an hourly rating of approximately 3 750 H.P. and a continuous rating of 3 300 H.P. They will be suitable for hauling 500-ton trains on the level and 240-ton trains up a grade of 1 in 166 at a speed of 90 m.p.h. They will be fitted with the Brown-Boveri system of individual axle drive, 5 ft. 9 in. wheels, and will scale 135 tonnes, of which 80 tonnes will be available for adhesion. In view of the level character of the route, regenerative braking will not be incorporated. The general service locomotives are to be of the Bo + Bo type with an hourly rating of 1 740 H.P. and a weight of 80 tonnes.

621.335 (.44)]

4. — Paris-Orleans high-power trial locomotive for 1 500-volt D. C. lines.

(*Electric Railway Traction*, Supplement to *The Railway Gazette.*)

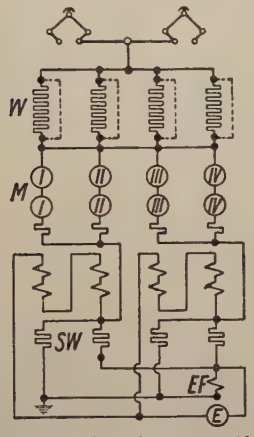
In addition to the 25 electric locomotives of 4 000 H.P. which the Paris-Orleans Railway ordered some three years ago, and which were equipped with Brown-Boveri individual axle drive, four further trial locomotives were ordered, more particularly with a view to



New Oerlikon locomotive of 4 000 H.P. and the arrangement of the control gear in the central compartment.

service on the heavily-graded line from Vierzon to Brive, then in course of electrification, and now completed. Two of these four test locomotives were ordered from the Maschinenfabrik Oerlikon, and they have now been delivered.

Of the standard 2-Do-2 wheel arrangement, these locomotives have a continuous rating of 4 220 h.p. at 55 m.p.h. and a one-hour rating of 4 780 h.p. at 52 m.p.h. on a working order weight of 134 tons, the respective tractive efforts being 27 300 and 33 000 lb. The maximum speed normally will be 87 m.p.h. over the Paris-Tours and Les Aubrais-Vierzon sections (if the French legal maximum of 74 1/2 m.p.h. is raised) and 53 m.p.h. over the Vierzon-Brive division, but the equipment is safe for speeds of over 90 m.p.h.

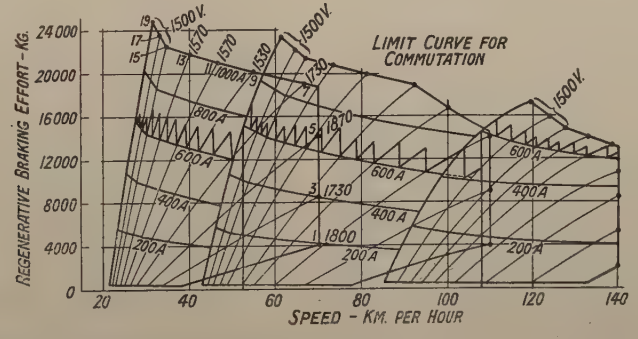


M = Traction motors (double armature).
W = Series resistances.
E = Generator of motor-generator set.
EF = Counter compound winding.
SW = Stabilising resistances.

Diagram of main connections during regenerative braking.

Steel has been used generally in the construction of the locomotive body, but in order to keep within the prescribed weight limit, certain details have been made of light metal. The electrical apparatus is arranged along the centre of the long compartment between the two driving cabs with a passage down each side and a transverse gangway across the centre. Doors and protective screens in the apparatus compartment are interlocked mechanically with the isolating switches to prevent possible contact with equipment under the contact line tension of 1 500 volts.

Four double-armature traction motors, entirely spring-borne, drive the wheels through the medium of the Oerlikon individual axle drive. At least two armatures are always in series so that the windings will not be fed with a tension exceeding half the line voltage. The speed of the traction motors is varied by regulating series resistances, or by weakening the field, and by providing three motor groupings, a total of 15 economical running speeds has been obtained. Individual resistances and field weakening steps are short-circuited by electro-pneumatic contactors. Two main contactors are used to protect each traction motor set, and the rupturing capacity of these two contactors in series



Regulation curve for regenerative braking of the new P. O. 4 000-h.p. Oerlikon locomotive showing the braking forces available over the full speed range.

is about 4 200 amperes at 1 800 volts. To prevent flash-over on the negative pole they are mounted separately and screened by an insulated arc chute.

For the interruption of short circuits on the locomotive the main contactors are released by means of maximum current relays with time lag, which operate the air valves of the contactors through the intermediary of an auxiliary relay. The control circuits of the locomotive are operated at a tension of 72 volts, the current being supplied by a cadmium-nickel alkaline battery of 48 cells, which is charged by the current of the fan and compressor motors. The lighting circuits are also on this 72-volt supply.

Regenerative braking on the Oerlikon system has been incorporated for use on the long 1 in 100 grades between Vierzon and Brive, and can hold the locomotive and train at all speeds from 87 to 15.5 m.p.h., although 53 m.p.h. is the maximum at present permitted over this sharply-curved line. During regeneration the four traction motors work as separately excited generators, the excitation being provided at variable pressure by the motor-generator set, which is operated direct from the contact line. In order to minimise the effect of the fluctuations in the contact line pressure on the regeneration, the generator *E* (see wiring diagram) is provided with a counter-compound winding *EF*, and stabilising resistances *SW* are inserted in the main circuit. The regulation curve for the regenerative braking is shown in an accompanying illustration. In these P.O. locomotives the air brakes cannot be applied while the regenerative braking is on, but an electrically-operated air valve brings the continuous brake into action should a fault develop in the regenerative system.

[621 43 (.44)]

5. — Diesel-electric railcars for goods transport, Paris-Lyons-Mediterranean Railways.

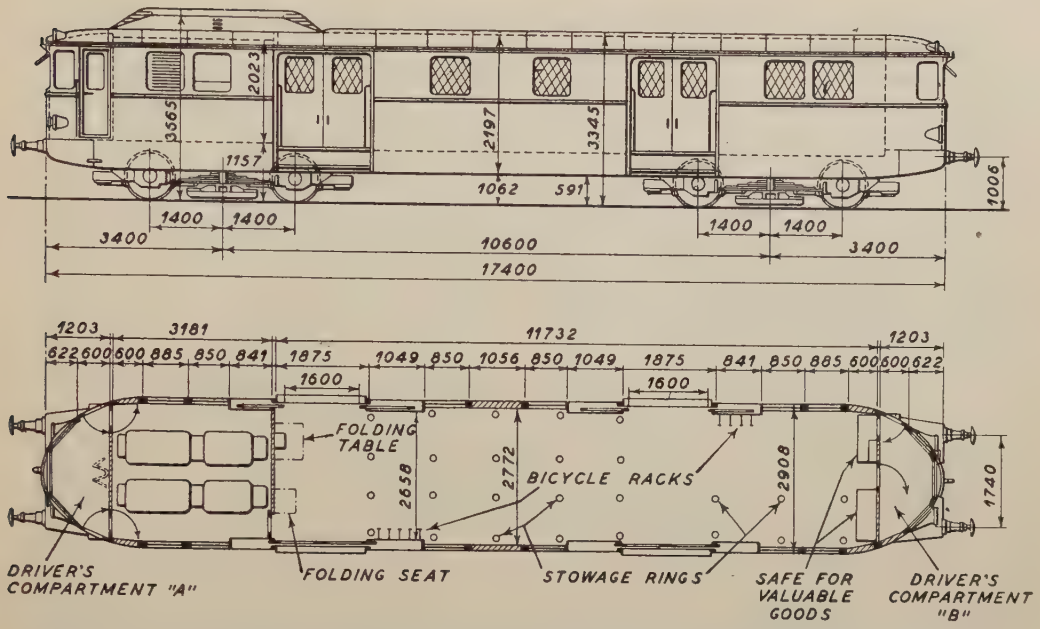
(From *Modern Transport*.)

An experiment which will be watched with interest is to be carried out by the Paris, Lyons and Mediterranean Railways, this consisting of the introduction of diesel-electric railcar services for the conveyance of goods. The new railcars, shown in the drawings hereafter, are generally similar in design to the units built by the Berliet Company for passenger services and will be capable of accommodating loads weighing up to 10 tons and to haul loads of approximately 60 tons. At the outset four of the new railcars have been constructed and the initial service is to be introduced in the Lyons district, there being one trip from Lyons to Grenoble, one from Lyons to Louhans, and one from Lyons to Valence daily. Should the experiment prove successful in speeding up express goods traffic, similar services will be introduced at other important centres on the P. L. M.

The underframes of the new Berliet railcars are built up of pressed steel members, the body structure also being of pressed steel covered, on the outside, with sheet steel, whilst the inside walls and the roof are lined with sheet aluminium. The frames of the leading power bogie and of the rear carrying bogie are built up of steel plates and sections, the bogies being attached to the journals by means of helical springs and connected to the underframe by means of a spherical pivot and two laminated springs. The coupling arrangement differs in certain respects from that generally incorporated in railcar design, this taking a form similar to that of conventional railway practice, though of lighter weight. The railcar can be driven from either end.

Engines and transmission.

The power equipment of the P. L. M. goods railcars consists of two six-cylinder diesel engines and generators, the cylinders having a



Drawings showing general arrangement and principal dimensions of the new Berliet diesel-electric railcars for express goods services on the Paris, Lyons and Mediterranean Railways, France.

stroke of 7.09 inches and a bore of 5.32 inches, and developing a nominal power of 125 H.P. at 1 500 r.p.m. The fuel is injected by means of Bosch pumps. Actually, it is possible for the speed of the motors to be varied to 600 r.p.m., 1 000 r.p.m., 1 250 r.p.m., and 1 500 r.p.m. respectively, control being exercised by means of a Bosch automatic regulator of the centrifugal type, while to start the diesel engines an electric starter is provided, this being automatically governed. Cooling of the engines is achieved by means of a radiator arranged on the roof of the cars, through which the cooling water is forced by a double centrifugal pump. The transmission, which is of the Alsthom Royer type, comprises two direct-current generators with variable excitation, these, which are directly coupled to the diesel engines, being capable of a steady output of 175 amperes at 435 volts.

The traction motors, which are of the self-ventilating type, are mounted on the bogies, and are connected to the driving shafts through gears having a ratio of 68 to 15 and electro-pneumatically controlled reverse box. The maximum speed of the railcars is approximately 54 m.p.h.

Braking arrangements.

The interior arrangement of the railcars may be seen by reference to the accompanying drawings. The wheels, which are constructed of chrome molybdenum steel, have a diameter of 2 ft. 11 2/5 in. and are of the standard railway type equipped with Timken roller bearings. As it is intended to use the railcars, when required, for the haulage of from one to five goods vans, the braking system incorporated has been designed to provide for this eventuality. Thus, in addition to the brakes installed for use on the railcar when travelling alone, a second equipment is incorporated for service when a train is being hauled. For the use of the railcar when travelling alone, a handbrake is provided in each of the driver's compartments, these acting on

the brake shoes of the appropriate bogie wheels. A Westinghouse oleo-pneumatic brake is also provided, this acting on all wheels, whilst an electro-magnetic brake acts on the shoes in contact with the rails. The Westinghouse brake is arranged with a double control, so that, through the medium of a regulator situated in the driver's compartment, the apparatus acts on the railcar alone, or, alternatively, by manipulating a second control lever, or by using the emergency brake in the guard's van, the whole train may be braked.

The railcars are heated by means of hot air from the diesel engines, whilst electric light is provided by storage batteries charged by two constant-voltage generators placed at the ends of the main generator shafts. The weight of the railcar, in running order, is approximately 35 tons, the adhesive weight being about 21 tons 10 cwt. During tests carried out under working conditions, the railcar alone, travelling over level track, attained a speed of 54 m.p.h., the same speed being maintained when hauling a 30-ton load, and 48 m.p.h. being reached with a 60-ton load.

[621. 43 (.44)]

6. — 1 000-B. H. P. diesel mechanical trains for the French State Railways.

(*Diesel Railway Traction*, Supplement to *The Railway Gazette.*)

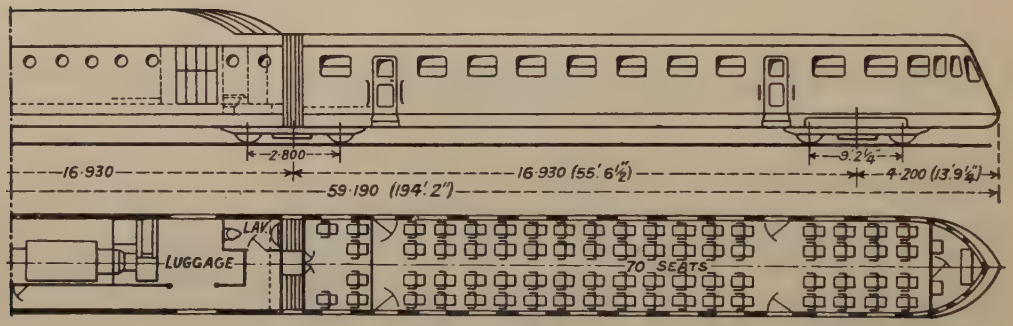


Fig. 1. — Diagram of half of three-car 1 000-B.H.P. diesel train for the French State Railways.

The French State Railways have placed an order with the Renault Company, of Billancourt, France, for three triple-articulated streamlined diesel trains, which will be unusual among trains of such power in that they will have mechanical transmission. These units are to be powered by 500-B.H.P. engines, two of which, with their attendant transmission sets and auxiliaries, will be located in the short centre vehicle of the train. The first two of these new engines are finished, and we have had the opportunity of inspecting them at the maker's works. The train is to be suitable for a normal maximum operating speed of 140 km.p.h. (87 m.p.h.), but it is probable that higher speeds will be obtained on the trials by increasing the engine revolutions. The central vehicle will contain luggage and lavatory accommodation in addition to the power equipment. At the moment, only third-class seats and a small number of seconds are proposed, but eventually one, at least, of these trains may be fitted with a buffet-bar. The train is to be articulated as one unit, with the power bogies beneath the joints and carrying bogies at the extremities.

The body and underframe of each vehicle will be fabricated as one structure, in accordance with standard Renault practice, the framing being of light steel stampings welded together, with inner and outer panels of sheet aluminium. The bogies will have one-piece rolled steel wheels with nickel steel axles running in S. K. F. roller bearings. The weight of the train with supplies but without passengers is estimated to be about 90 tonnes.

The engine.

In general design the engine is similar to the Renault 12-cylinder V engine of 250/265 B.H.P which is running in large numbers in railcars on the various French railways, but the 500-B.H.P. engine is not simply an enlargement of this unit, it is a new model, with 16 cylinders arranged in two banks of eight. The cylinders have a bore and stroke of 156 mm. by 180 mm. (6.16 in. by 7.1 in.) compared with the 140 mm. by 170 mm. (5.53 in. by 6.7 in.) of the 250-B.H.P. 12-cylinder engine. The rotational speed is 1 500 r.p.m., the piston speed 1 770 ft. per min., the brake m.e.p. 77 lb. per sq. in., and the weight about 17 lb. per b.h.p. The crankshaft rests on nine plain bearings supported by the lower part of the crankcase; it is of the counterbalanced type, and is constructed of nickel-chrome-molybdenum steel with an ultimate strength of 115 kgr. per sq. mm. (74 tons per sq. in.). Each set of rods consists of a main unit to one cylinder with a smaller articulated rod to the corresponding cylinder of the opposite bank, so that the cylinders of the two banks are not offset. In the first two 500-B.H.P. engines (now completed) the main bearing on the crankpin, the articulated joint, and the gudgeon pin of the cylinder with the small connecting rod, are fitted with needle roller bearings. The pistons are of aluminium alloy, and have four pressure and two scraper rings. The fuel injection is on the direct system, with a central nozzle spraying fuel outwards round the cylinder.

The cylinder block and crankcase are cast in one piece of aluminium alloy, with nine rigid cross braces carrying the main bearings; cast iron liners are inserted in each barrel. In the crankcase are six large doors through which dismantling of the rods and bearings can be accomplished, and there are 16 smaller doors in the cylinder block and casing for inspection and adjustment purposes. The separate cylinder heads are also of cast aluminium alloy; they carry two inlet and two exhaust valves, an arrangement adopted to clear as far as possible the burnt gases from the cylinders and thus give the requisite power with low temperatures and stresses, and to avoid trouble through excessive temperature and distortion in large valves. Previous Renault engines have been fitted with the Bosch fuel pump, but this new 500-B.H.P. engine incorporates a special Renault pump, comprising an aluminium pump box carrying on five bearings the driving shaft with 16 cams arranged in four sets of four. In the French 1 000-B.H.P. trains, each engine is to have a further fuel pump with automatic action for feeding the fuel from the tanks to the injection pumps. The fuel injection pump is gear-driven from the crankshaft, and so is the cooling water pump. Each engine is equipped with two electric starting motors, a lighting and auxiliary dynamo, and a belt-driven compressor for the air brakes, clutch, and electro-pneumatic control system. Gilled-tube radiators for the engine cooling water will be located on the roof of the centre vehicle.

The transmission.

The main clutch is of the friction type with steel plates having Ferodo linings. The faces are maintained together by springs, and clutching and de-clutching operations are carried out by compressed air, and as this operating air is able to circulate over the interior and exterior of the clutch, it keeps the rubbing surfaces cool during frequent clutch operations.

The gearbox is of the constant-mesh type with four speeds having ratios of 1.0, 1.63, 2.76, and 4.9 to 1. Intermediate trains of wheels are inserted between the first and second and between the third and fourth speeds. The pinion shafts are carried on

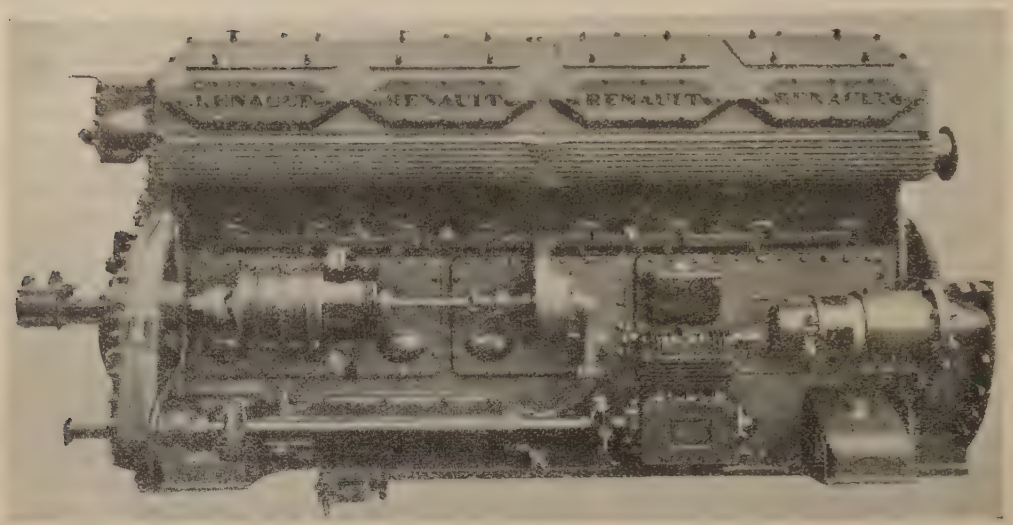


Fig. 2. — Renault 16-cylinder V engine with a continuous output of 500 B.H.P. at 1 500 r.p.m.

taper roller bearings. Pre-selection and changing of the gears is effected electro-pneumatically by Jourdain-Monneret apparatus fixed on top of the gearbox, which is cast of aluminium alloy. The reversing gear is located adjacent to the gearbox and not in the final drive on the axles; it is operated on the same electro-pneumatic principle as is used for gear changing. The final drive to the axle is through a modification of the standard Renault method of a cardan shaft leading from the gearbox to bevels on one axle, and thence by other bevels and another cardan shaft to the remaining axle of the bogie. Electro-magnetic brakes of the Jourdain-Monneret type are to be fitted to all four bogies, and will operate rail shoes in the centre of the bogie wheelbase.

[621. 43 (44)]

7. — 12-cylinder engines for Paris-Lyons-Mediterranean Railway diesel-electric railcars.

(*Diesel Railway Traction*, Supplement to *The Railway Gazette*.)

A new high-power model of the Saurer engine is to be installed in nine large double-bogie railcars now being constructed by the Decauville Company for the Paris, Lyons & Mediterranean Railways. It is just twice the power of any Saurer engine so far used in railway work, and is formed by combining two of the six-cylinder 150-B.H.P. BXD type engines into one 12-cylinder V unit giving a continuous output of 300 B.H.P. at 1 500 r.p.m. This output and the corresponding one-hour rating of 330 B.H.P. at 1 500 r.p.m. are considered by the maker as conservative values suitable for railway work.

The cylinders have a bore of 130 mm. (5 1/8 inches) and a stroke of 180 mm. (7 3/32 inches), and are set at an angle of 60°. The firing order is 1 right, 6 left, 5 right,

2 left, 3 right, 4 left, 6 right, 1 left, 2 right, 5 left, 4 right, 3 left. The crankcase is a single casting, of iron, and has mounted upon it four cylinder blocks, each block covering three cylinders. These blocks are of cast iron, and each barrel is fitted with a dry-type cast-iron liner. The use of cast iron extends also to the cylinder heads, which are cast in groups of three, corresponding to the cylinder blocks. An unusual feature for cylinders of only 130 mm. bore is the provision of two inlet and two exhaust valves, all of which are driven from a single centrally-located camshaft, each pair of valves being actuated through the medium of a push rod and two short rockers, one of which is moved by the other. The camshaft is carried on seven plain bearings, and is driven from the crankshaft by helical gearing.

Bosch fuel pumps are used in conjunction with Saurer fuel injectors in the cylinder heads. The head presents a flat surface to the combustion space and the Saurer form of air cell is in this type incorporated in the piston crown. Each injector has four horizontal orifices of about 0.35 mm. (0.0137 inch.) diameter and is set for an injection pressure of about 200 atm. (2 900 lb. per sq. in.). The case-hardened crankshaft is of the normal Saurer type with seven roller bearings, which are of exceptionally large diameter, as actually the crank webs form the bearings, and give a very rigid shaft. Another unusual feature is that each pair of connecting rods are not articulated (in order to keep the corresponding cylinders of each bank in line), but one big end is forked over the other. The connecting rods are nickel-steel drop stampings and are fitted with plain bronze bearings at each end. The governor for regulating the engine speed is integral with the fuel pumps. Forced lubrication is provided by two pumps, the

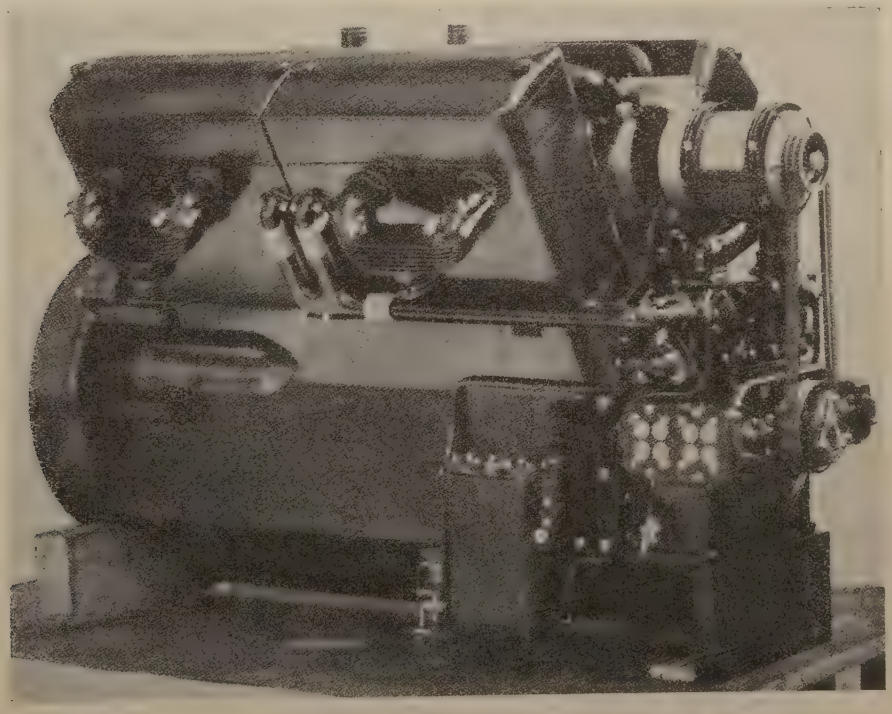


Fig. 1. — General view of 300-B.H.P. Saurer BZD diesel engine.

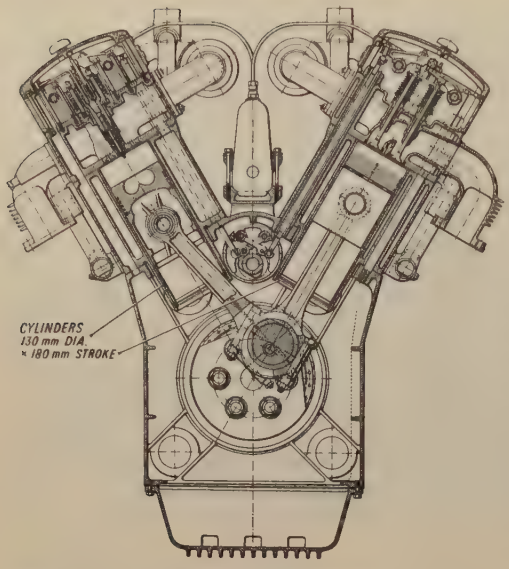
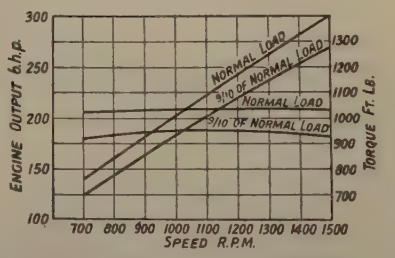


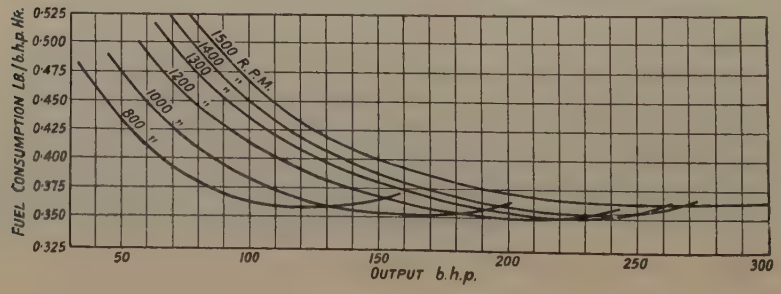
Fig. 2. — Sectional arrangement of 300-B.H.P. Saurer engine.

first supplying oil to the main and connecting rod bearings, timing gear, servo-governor and air compressor, and the second (at a lower pressure) to the camshaft bearings and rockers. A water-cooled oil filter is installed. A large capacity light-metal sump is fitted to the bottom of the crankcase, and its under surface has ribs cast on. Twin centrifugal engine-driven pumps circulate the cooling water. Other standard auxiliaries include a 15-H.P. starting motor, a 1.25-kw. 24-volt dynamo, and an air compressor for the railcar brakes.

Tests conducted on behalf of the P. L. M. Railways, in some of whose new Decauville railcars these engines are to be installed, showed that during 72 hours continuous running at normal load the mean consumption was only 0.357 lb. per B.H.P.-hour, the maximum and minimum values being 0.355 and 0.366 lb. per B.H.P.-hour; the highest values were reached shortly after the beginning of the test. The lubricating oil consumption was 0.0055 lb. per B.H.P.-hour and the maximum exhaust temperature 900° F. At the conclusion of this test short bursts of 10 % overload and 10 % overspeed were carried satisfactorily. Further trials at part load showed that when developing 0.33 full load (100 B.H.P.) at full speed (1 500 r.p.m.) the consumption was 0.465 lb. per hour, but when the speed was lowered to 1 000 r.p.m. for this

Fig. 3. — Fuel consumption and torque curves of Saurer 300-B.H.P. high-speed light-weight BZD diesel engine. Noteworthy points are the flat contour of the fuel consumption curves at various loads within the usual speed range, and the way in which the torque is maintained.





output, the consumption fell to 0.382 lb. per B.H.P.-hour. At three-quarters to full speed the consumption curve was very flat between the limits of full load and 60 %. When desired for railcar work, this new Saurer engine can be set to give three or four speeds between about 800 r.p.m. and the normal maximum of 1 500 r.p.m. In the ordinary way it idles at 450 r.p.m. Tests made by Professor Nägel, of the Dresdener Hochschule, on one of the BXD engines from which the above BZD type was developed, showed that a m.i.p. of 125 lb. per sq. inch. could be maintained, although the fuel consumption did not exceed 160-170 gr. (0.353-0.375 lb.) per B.H.P.-hour.

NEW BOOKS AND PUBLICATIONS.

[385. 517 (.44)]

L'effort social des Grands Réseaux de Chemins de fer en faveur de leur personnel (*Staff social betterment work on the French main lines railways*). — A pamphlet (8 3/4 × 5 1/2 inches) of 132 pages. — 1935, Published by *Le Musée Social*, 5, rue Las Cases, Paris.

The French main-line railways had a large share in the French participation in the Brussels Universal and International Exhibition of 1935. If the visitors were able to admire characteristic examples of the railways' achievements in technical matters, they were also given the opportunity of studying the railways' latest efforts to promote the professionnal education and the social improvement of their staff.

The exhibits in connection with the latter field were classified into two groups, in two rooms of the French Pavilion. The first covered the work done in connection with technical education, apprentice training, applied psychology and physiology, and domestic economy. The other group contained the charts, diagrams, models, etc. showing the investigations carried out and the work done to improve the living conditions of the staff.

The object of the *Musée Social* in publishing this pamphlet was to give its readers a summary of the documents exhibited, so as to increase their edutional value and make it more lasting. The author, moreover, by enlarging the scope of his subject, has given a general review of the French railways' social betterment work as a whole.

Dealing first of all with the employee *in relation to his domestic life*, the author shows what has been done in the way of housing and organisations through which the staff can purchase commodities at cheap rates. This first part is completed by particulars of the different steps taken as regards child welfare, the intellectual, artistic, and sports training of the employees and their families, and finally the loans, and mutual assistance offices.

The author in the *second part* deals with the way the railways look after their employees as regards *their professional career*. First of all a brief account is given of the whole scheme of technical and professional education given either directly by the Companies or under their supervision. The working conditions, accident and sickness prevention, and medical services are then described.

The third and fourth parts are devoted to the pensions scheme and to mutual aid. The railways acknowledge the work done by their staff on their own by supporting such social work.

This general review enables the reader to gauge the considerable amount of work done by the railways in this field and to appreciate the results obtained. The documents exhibited at Brussels are given as an appendix and form as it were the illustrations.

E. M.

[621. 43]

PUERTAS (D. Emilio Santiago). — **Automotores ferroviarios con motor independiente** (*Rail motor cars*). — Published by the « Asociacion general de transportes por via ferrea ». — A pamphlet (9 1/2 × 6 1/4 inches) of 76 pages, with many illustrations. — 1935. Published by the said *Asociacion*, Calle del Prado, 26, Madrid.

The « Asociacion general de transportes por via ferrea » has added to its series of pamphlets on railway operation by publishing the interesting study on diesel-engined rail motor cars, by Señor Emilio Santiago Puertas, Assistant Manager of the Madrid Saragossa & Alicante Railways.

This paper is a brief but very methodical review of the present position of the problem of working passenger services by rail motor cars.

The author first of all shows the unfavourable operating results obtained with certain classes of passenger trains when worked by steam engines, and then stresses the necessity for modernising the working of secondary lines by using internal - combustion - engined railcars. He then deals with the comparative values of petrol and diesel engines and concludes in favour of the latter for this application.

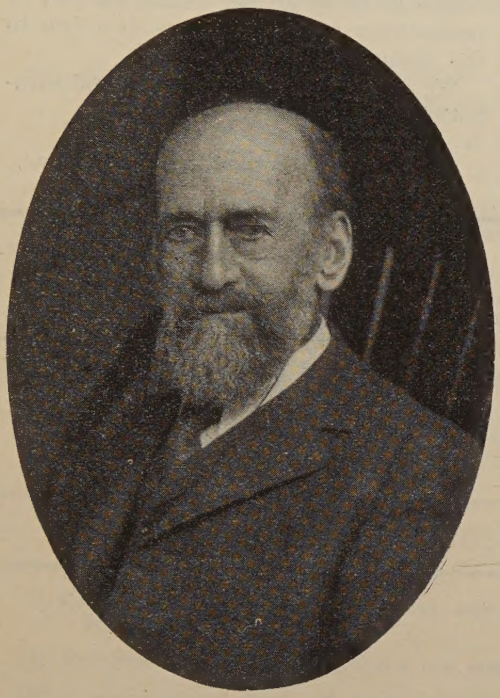
The author then analyses the characteristics and the technical and commercial advantages of a diesel railcar service. He gives particulars of the principal types of such railcars and their development and also of the principal systems of transmission and control. He then examines in detail the economics of the use of railcars. The paper also touches on diesel locomotives, both for shunting and train working. It ends with a general comparison between steam, diesel, and electric traction, the field of each of which is delimited, and with an investigation into the position of the Spanish railways and industry as regards diesel railcars.

A. C.

OBITUARY.

GUSTAV BEHRENS,

Former Director, London Midland & Scottish Railway,
Honorary Member of the Permanent Commission of the International Railway Congress Association.



We deeply regret to record the death, at the age of 90, of Mr. GUSTAV BEHRENS, who for 45 years was a Director of the Midland Railway and its successor, the London Midland and Scottish Railway.

He was born and educated at Bradford. His first business interest was in textiles. In 1889, he became the head of the firm founded by his father, and whose interests covered most parts of the world.

Meanwhile, in 1886, at the age of 30, he was appointed a Director of the Midland Railway. From time to time, he was appointed on no less than thirty Committees; at different periods, he served as Chairman of the Midland Stores Committee, Midland Way and Works Committee, and Traffic Committee.

In 1895, he was appointed on the Cheshire Lines Committee and he always took a great interest in joint lines, and at the time of his retirement was a member of the London and North Eastern and London Midland & Scottish Railway Group Committee No. 1.

On the 1st January, 1923, when the British Railway Amalgamation Act came into force, Mr. BEHRENS joined the Board of Directors of the London Midland & Scottish Railway. At the General Meeting in February 1931, Sir Josiah Stamp, Chairman of the L. M. S. R., stated that in the course of his 45-year tenure, out of 672 possible attendances, Mr. BEHRENS had been present at 655 Board Meetings, besides thousands of Committee Meetings.

He was one of the founders of a number of institutions having for their object the welfare of the staff and their families.

In 1895, Mr. BEHRENS became a member of the Permanent Commission of the International Railway Congress Association. He most regularly attended its meetings and his genial disposition, outstanding business ability and wide knowledge of languages, were much appreciated.

He was a delegate of the Midland Railway at the third, fourth, fifth, sixth, seventh, eighth and ninth Sessions of the Railway Congress (Paris, 1889 — St. Petersburg, 1892 — London, 1895 — Paris, 1900 — Washington, 1905 — Berne, 1910 — Rome, 1922) and of the

London Midland & Scottish Railway at the tenth Session (London, 1925).

He also was a member of the British Local Organizing Committee at the 5th Session (London, 1895), Vice-President of the British Local Organizing Committee at the 10th Congress (London, 1925), and Vice-President of the latter Session. He was Vice-President of the 5th Section at the London Session (1895), President of the 5th Section at the Berne Session (1910), and President of the 3rd Section at the Rome Session (1922).

In 1901, Mr. BEHRENS was appointed a member of the Executive Committee of the Permanent Commission.

The last Meeting he attended was in July 1929, when he reluctantly told his colleagues that, owing to his old age, he would no longer be able to cross the Channel and meet the many friends he had made in the foreign railway world.

Mr. BEHRENS was then nominated an honorary Member of the Permanent Commission as a mark of the high esteem he was held in by all his colleagues and in recognition of his ceaseless devotion to the Association.

We wish to convey our sincerest sympathy to his family.

The Executive Committee.

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CONTENTS OF THE NUMBER FOR JUNE 1936.

CONTENTS.	Page.
I. **Competition by roads, waterways and airways:** Italy, Algeria, French Indo-China	563
II. **Resonance in rolling stock,** and a few **methods to meet it,** by P. LEBOUCHER.	567
III. A comparature **study of motor transport regulation** (third article), by Vladimir IBL.	582
IV. **Railway curves.** A new method of surveying lines on curves and of calculating the angle at the centre by means of the diagrams of the versines, by Mr. CHAPPELLET	598
V. Note on **train speeds,** by Lionel WIENER: Part II (*continued*): **Train speeds and services in different countries** — XVI: **Denmark** (*to be continued*)	609
VI. Railway **maintenance** problems. **Permanent way,** by Lt. Col. H. A. HULL	641
VII. Santa Fe's new 3 600-H.P. **diesel-electric locomotive** makes record run	645
VIII. The new **research laboratory** at Derby, London Midland and Scottish Railway	651
IX. The Dutch **diesel train failures**	657
X. NEW BOOKS AND PUBLICATIONS:	
Neuere Methoden für die Betriebsuntersuchungen der Bahnanlagen (*Modern methods of analysing the working of railway equipment*), by Dr.-Ing. Wilh. MÜLLER	659

CONTENTS (*continued*).	Page.
Fifty years of railways in Malaya — 1885-1935	660
Great Western progress, 1835-1935	661
Las tarifas ferroviarias y su ordenamiento y unificación (*Railway rates : Their harmonisation and standardisation*), by A. I. DIAZ	661
Traction nouvelle. No. 1, January-February 1936	662
Aus der Früheit der Eisenbahnen (*The railways in their early stages*), by Dr. Max HOELTZEL	663
Locomotive Engineer's Pocket Book, 1935	663
The **horse-power of locomotives : Its calculation and measurement**, by E. L. DIAMOND	664
XI. MONTHLY BIBLIOGRAPHY OF RAILWAYS	75

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